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How can a Marine Aviation Logistics Squadron be measured for effectiveness?

Millikin, Patrick K.

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THESIS

HOW CAN A MARINE AVIATION LOGISTICS SQUADRON BE MEASURED FOR EFFECTIVENESS?

by

Patrick K. Millikin

December 2016

Thesis Advisor:	Chad Seagren
Second Reader:	Kenneth Doerr

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HOW CAN A MARINE AVIATION LOGISTICS SQUADRON BE MEASURED FOR EFFECTIVENESS?

Patrick K. Millikin
Captain, United States Marine Corps
B.S., Appalachian State University, 2005

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requirements for the degree of

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December 2016

Approved by: Chad Seagren
Thesis Advisor

Kenneth Doerr
Second Reader

Chad Seagren, Academic Associate
Graduate School of Business & Public Policy

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ABSTRACT

This thesis examines current metrics used by a Marines Aviation Logistics Squadron (MALS) and how a MALS can be measured for overall performance in regard to supporting flight-line squadrons. Currently, used primary metrics are analyzed for their ability to reflect the level of support a MALS provides, the behavior that those metrics incentivize, metrics that should be adopted, and how standardized metrics can be used to compare performance between various MALS. Supply shelf items with a critically low physical buffer status, supply chain response time, and supply effectiveness for high-priority parts are found to be the best metrics for overall performance measurement. These metrics, when measured specifically according to the various type/model/series of aircraft a MALS supports, constitute a performance measurement system that can be used by aviation logistics leaders to compare various MALS.

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LIST OF ACRONYMS AND ABBREVIATIONS

AFLMA	Air Force Logistics Management Agency
AFMC	Air Force Materiel Command
AMSRR	aviation maintenance and supply readiness reporting
AMO	Aircraft Maintenance Officer
AO	area of operation
ASO	Aviation Supply Officer
AVCAL	aviation consolidated allowance list
AVLOG	aviation logistics
AWP	awaiting parts
BCM	beyond capability of maintenance
BMT	buffer management tool
CNO	Chief of Naval Operations
CPI	continuous process improvement
CWT	customer wait time
DIFM	due in from maintenance
DON	Department of Navy
EDD	estimated delivery date
EPAT	enterprise project alignment tool
EPUK	expeditionary pack-up kit
EVA	economic value added
EXREP	expeditious repair
FCF	functional check flight
FMC	full mission capable
FOB	forward operating base
GAC	goal alignment chart
I-Level	intermediate level
IM	item manger
IMA	intermediate maintenance activity
LMI	Logistics Management Institute
LOGREP	logistics replenishment
LTD	long term down

LPT	logistics planning tool
LRT	logistics response time
MAF	maintenance action form
MAG	Marine Aircraft Group
MAL-EIT	Marine Aviation Logistics Enterprise Information Technology
MALS	Marine Aviation Logistic Squadron
MALSP	Marine Aviation Logistics Support Program
MALSP MOD	Marine Aviation Logistics Support Program Modernization
MAW	Marine Aircraft Wing
MC	mission capable
MMCO	maintenance material control officer
MMH	maintenance man hour
MOB	main operating base
MTBF	mean time between failure
NAE	Naval Aviation Enterprise
NALCOMIS	naval aviation logistics command maintenance information system
NAMP	naval aviation maintenance program
NC	not carried
NGBMS	Next Generation Buffer Management System
NIS	not in stock
NMCS	not mission capable supply
OPNAVINST	Office of the Chief of Naval Operations Instruction
PMALS	parents Marine Aviation Logistics Squadron
PMCS	partial mission capable supply
RBA	ready basic aircraft
RFI	ready for issue material
SCM	Supply Chain Measurement System
SCOR	Supply-Chain Operations Reference Model
SOP	standard operating procedure
SOW	site opportunity worksheet
TAT	turnaround time
T/M/S	type/model/series
TRR	time to reliably replenish

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I. INTRODUCTION

A. GENERAL OVERVIEW

A Marine Aviation Logistics Squadron (MALS) provides intermediate maintenance and supply support for flight-line squadrons. A MALS might support flight-line squadrons that all operate the same type/model/series (T/M/S) aircraft or squadrons with different T/M/S aircraft. Each T/M/S has its own support network within the greater aviation logistics (AVLOG) community.

Determining the level or quality of support that a MALS is providing its flight-line squadrons is quite difficult. This is because a MALS performs so many different types of support functions that knowing what should be measured can be unclear. Each of these support functions also consists of many other sub-functions, cooperating to produce a final output, whether that output is a part or a service.

The civilian sector utilizes many different methods of measuring performance in its organizations and several are universally agreed upon as best business practices. Applying these performance measurement systems directly to a MALS is difficult for many reasons but primarily because financial measurements are a large part of these civilian measurement systems. Furthermore, the supplier-customer relationship in the civilian sector is not identical to the MALS-flight line relationship in AVLOG.

This thesis addresses these issues, and answers three primary questions and one secondary question.

1. Primary Questions

- Of the metrics that MALS currently employs, which measures (or combination thereof) most appropriately reflect the level of support the MALS provides the flight-line?
- Of the metrics that MALS currently employs, which measures most appropriately incentivize the most beneficial behavior to support the flight-line?
- Are there metrics that MALS does not employ that should be adopted?

2. Secondary Question

- To what extent can standardized performance measurements be used to measure flight-line support performance between various MALS?

Many of the logistic metrics currently in use measure their respective processes sufficiently. These individual metrics, however, are unable to function as a performance measurement for the MALS as a whole. This is because they do not sufficiently measure the output of the MALS as a whole. A proper performance measurement system for a logistics organization will capture the output of that organization, where the output is a function of all the sub-functions within the organization. While a MALS has numerous and varied sub-functions and responsibilities, only those that directly contribute to the goal of the MALS are to be included in the performance measurement system.

Supply Effectiveness is found to be, of the metrics currently used, the metric that most appropriately reflects the level of support the MALS provides the flight-line. Repairable Physical Buffer Status Red and TRR-Supply are currently used metrics that incentivize the most appropriate behavior to support the flight-line. Supply Chain Response Time is an individual metric that should be adopted by the MALS that is not currently used. A weighted performance metric composed of three sub-metrics (Physical Buffer Status Red of Repairables, Supply Chain Response Time, and Supply Effectiveness) should be adopted as an overall performance system that unifies the command towards a common goal. Lastly, these metrics ought to be aircraft type/model/series specific in order to make comparisons of performance between various MALS.

II. BACKGROUND

A. INTRODUCTION

This chapter focuses on the current structure, organization, and measurement systems used in a Marine Aviation Logistics Squadron (MALS). The organizational structure of a MALS discussed here is specific to the current structure of MALS in garrison settings. The systems discussed are the various systems accessible to a MALS and are used to measure, report, analyze, or otherwise manage data. Any logistics or performance metrics used within a MALS are generally computed by these systems.

B. ORGANIZATIONAL STRUCTURE OF A MARINE AVIATION LOGISTICS SQUADRON

A MALS exists to provide aviation logistics (AVLOG) support of intermediate level maintenance and supply functions to flight line squadrons. A typical MALS consists of five departments: Maintenance, Supply, Avionics, Ordnance, and Headquarters. Due to their similarities and relationship, the Maintenance, Avionics, and Ordnance departments are collectively referred to as the Maintenance department in this thesis.

A MALS may support flight line squadrons that all fly the same type/model/series (T/M/S) aircraft but, more commonly, a MALS will support multiple squadrons with different T/M/S. This is depicted in Figure 1. MALS-24 in Hawaii, for example, supports one CH-53E squadron, one H-1 squadron that flies AH-1W and UH-1Y aircraft, four Navy P-3 squadrons (part of Commander, Patrol, and Reconnaissance Wing Two), and one H-60 squadron. Each squadron’s aircraft T/M/S is different from the others (with the exception of the P-3 squadrons). In practical terms, this means the supply and maintenance support required from the supporting MALS becomes more cumbersome and complex with each different T/M/S supported.

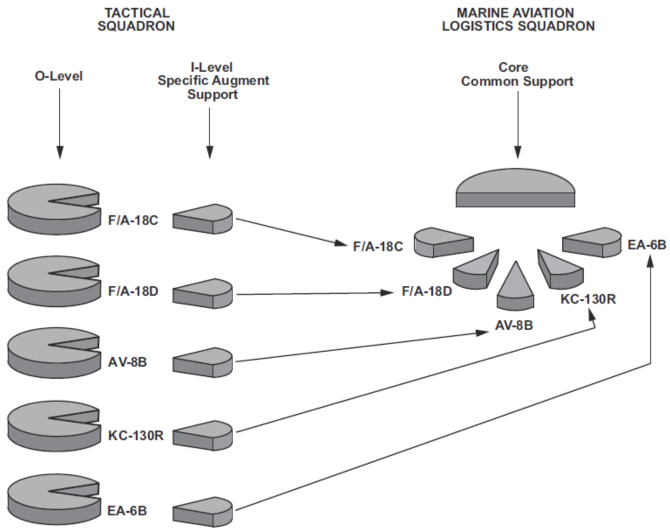

Figure 1. MALS Support Organization Example. Source: United States Marine Corps (2012).

The Aircraft Maintenance Officer, typically an O-4 limited duty officer, leads the Maintenance Department. According to the Marine Corps Warfighting Publication 3021.2, "the AVLOG functions of the MALS maintenance department include aircraft, avionics, ground support equipment (support equipment) maintenance, flight equipment, cryogenics, and maintenance data collection and analysis" (United States Marine Corps, 2012, p. 3-1). Each of these departments is broken down into divisions with each focusing on one major function. The Power Plants 400 division, for example, primarily focuses on engine overhauls. The Ground Support Equipment 800 division repairs and maintains large support equipment for use by the MALS and flight line squadrons.

The Aviation Supply Officer, typically an O-4 unrestricted officer, leads the Supply Department. The supply department "executes all storage, inventory, condition, and management functions of Navy-provided, aeronautical-related materiel" (United States Marine Corps, 2012, p. 3-4). For example, the Supply Response Division (SRD) is responsible "for the initial screening and technical research of all requisitions ordered through NALCOMIS" (United States Marine Corps, 2012, p. 3-4).

C. MALSP MODERNIZATION

A MALS is part of the larger Marine Aviation Logistics Support Program (MALSP). The MALSP framework was recently reconstructed and retitled MALSP Modernization, or MALSP MOD. MALSP MOD is "an expeditionary demand-pull logistics capability solution that aligns with national defense and security strategies, as well as: the long war concept, Marine Corps vision and strategy 2025, the maritime strategy, the aviation plan, and the aviation logistics (AVLOG) strategy" (Headquarters Marine Corps, 2016, p. 1).

Historically, MALSP functioned as a push supply system. A push supply system supports the end user by pushing resources forward to the user, regardless of whether requisitions for those resources have been made. This involves a large footprint of supply inventory and repair capability in forward deployed areas. An entire MALS would be moved to forward areas, providing intermediate level support to other deployed squadrons.

MALSP MOD seeks to create a pull supply system. A pull system's action is dictated by the demand signal produced by the customer. The paradigms on which MALSP and MALSP MOD are based are quite different. Rather than a supplier pushing parts to fill shelf space, parts are pulled by the customer to fill a demand. Rather than a large supply footprint forward deployed, a parent MALS (PMALS) supports deployed squadrons from garrison locations, as depicted in Figure 2. These PMALS send requisitioned parts forward according to a flight line squadron's demand signal. The logistics chain is established along various nodes between the PMALS and the deployed squadrons. Navy T-AVB ships, Main Operating Bases (MOBs), and Forward Operating Bases (FOBs) are used to link the PMALS with the squadrons.

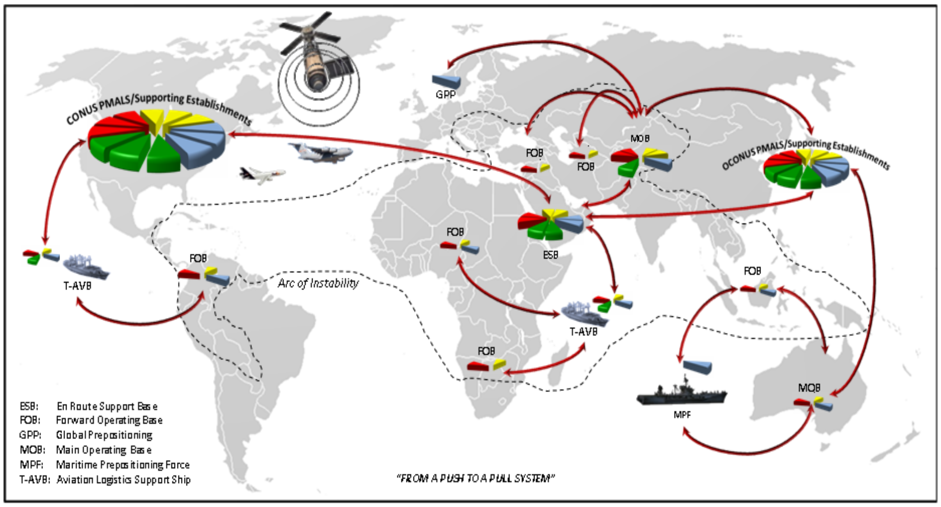

Figure 2. MALSP II Nodal Network. Source: Borrelli (2011).

A key aspect of MALSP MOD is the updated technology suite titled Marine Aviation Logistics Enterprise Information Technology (MAL-EIT) which will accompany the new program. With the intent of being a net-centric logistics chain, the next generation buffer management system (NGBMS), expeditionary pack-up kit (EPUK), and logistics planning tool (LPT) have been created to better support all MALS and squadrons in Marine aviation. These software packages, in combination with the nodal logistics chain, "provide more responsive, scalable, and flexible solutions through properly-sized spares packages while achieving near real time global visibility" (Headquarters Marine Corps, 2016, p. 2).

D. BUFFER MANAGEMENT TOOL

The current buffer management tool (BMT) is the primary software package designed for use by the maintenance and supply departments to prioritize repair and replenishment requirements. Division officers in the MALS are instructed to "use BMT reports (I-level) to monitor daily workload and assign priorities to ensure efficient movement of components through assigned work centers" (Department of the Navy, 2012, p. 3-92). The BMT is described in the Naval Aviation Maintenance Program (NAMP) as follows:

> [The BMT] pulls data from NALCOMIS and R-Supply databases to generate integrated reports that provide focus on what work has priority for repair and replenishment of buffers in a Time Domain. Monitoring consumable and repairable components, from a time domain perspective, gives supervisors the information they require to ensure they are working on the items that are a priority to the customer producing aircraft ready for tasking and not sub-optimizing resources by working on lower priority items. (Department of the Navy, 2012, p. A-9)

The BMT provides maintenance and supply managers with the requisite information to prioritize their work. It can produce a wealth of reports useful to maintenance managers, such as the expeditious repair (EXREP) report, work load report, and back log report. Other reports help managers identify what the next EXREP might be due to their buffer status as well as identify how the MALS may reduce costs caused by being unable to repair components in-house (i.e., causing a repairable to be considered beyond the capability of maintenance, or BCM). The supply BMT "provides activities with a means of monitoring and managing the time to reliably replenish (TRR) of all components under TRR Management. The TRR value of a requisitioned part starts from the time a requisition is ordered and ends when the requisition is completed" (NAVAIR 6.7.2.1, 2013, p. G-5).

The BMT prioritizes work according to its buffer status. The buffer status is determined by the item's TRR. The TRR is defined as "the total time it takes once a part is pulled from the Supply shelf until it is back on the Supply shelf ready for issue" (NAVAIR 6.7.2.1, 2013, p. G-30). To compute the TRR, the times to fill historical requisitions of a particular item are measured. The 90th percentile of those times is then applied as the TRR for that part (Seagren, 2013).

Each requisition has a color code assigned based on its buffer status. The buffer status has both a time and physical dimension. In regard to time, the code refers to how long it will take to repair the item and get it back on the supply officer's shelf ready for issue. Physical buffer status is characterized by how many items are on the shelf. The order of prioritization of work orders, in descending order of importance, is EXREPs, red, yellow, green, and black. Figure 3 is an example workload priority decision matrix demonstrating the interaction of the time and physical components of TRR.

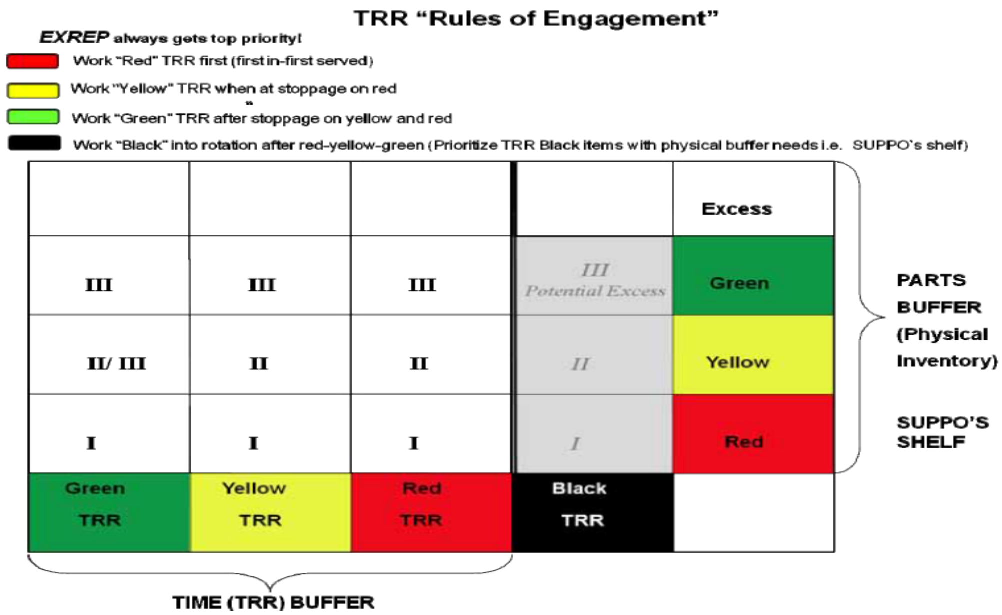

Figure 3. Example BMT Workload Priority Decision Matrix. Source: NAVAIR 6.7.2.1 (2013).

The Maintenance and Supply departments are able to extract a multitude of reports analyzing their current workload. Examples of the broad view of Supply Department's workload in terms of Requisition TRR, Consumable TRR, Repairable TRR, and Physical Buffer Status are provided in Figures 4, 5, 6, and 7.

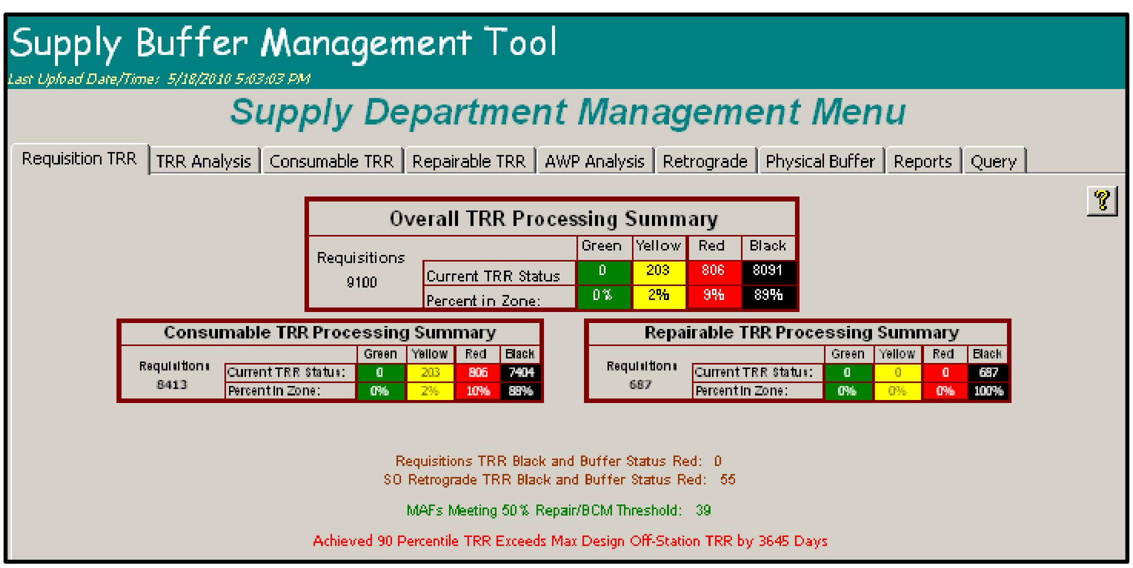

Figure 4. Supply Requisition TRR Summary. Adapted from NAVAIR (2011).

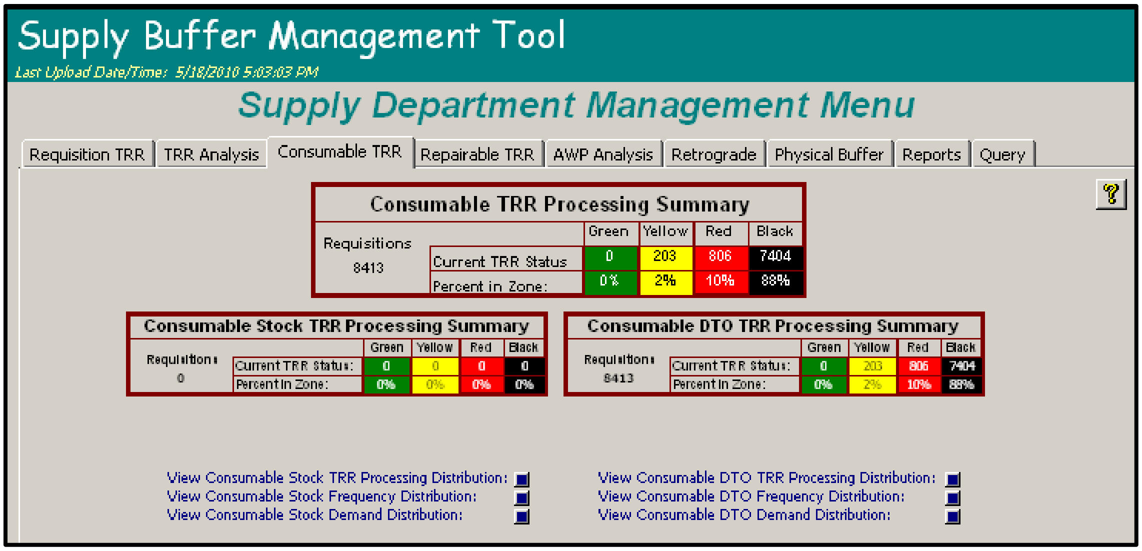

Figure 5. Supply Consumable TRR Summary. Adapted from NAVAIR (2011).

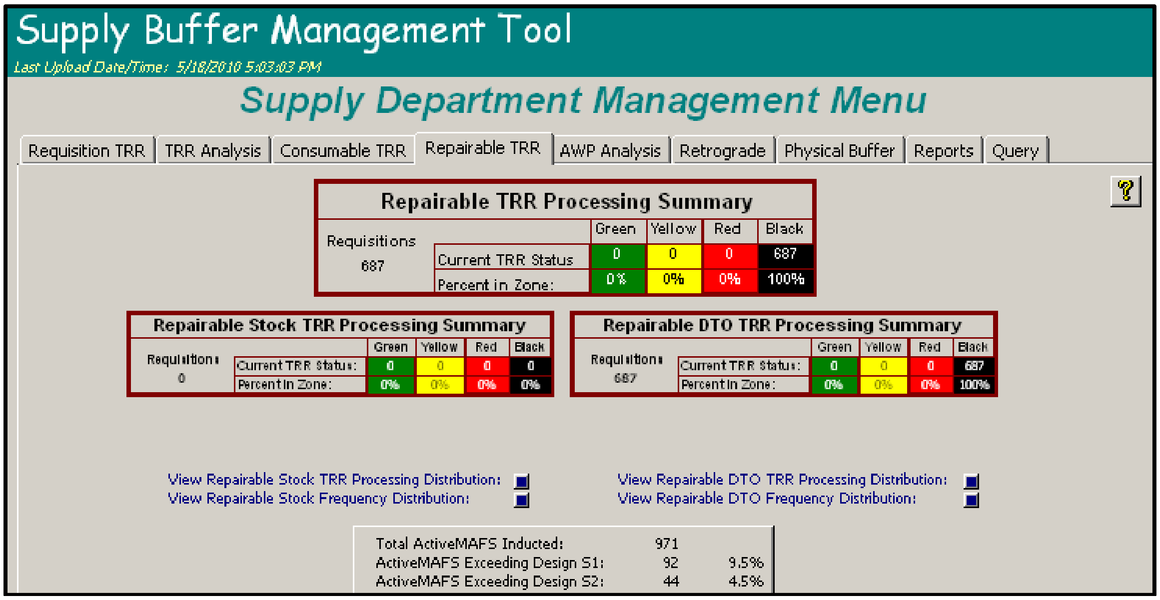

Figure 6. Supply Repairable TRR Summary. Adapted from NAVAIR (2011).

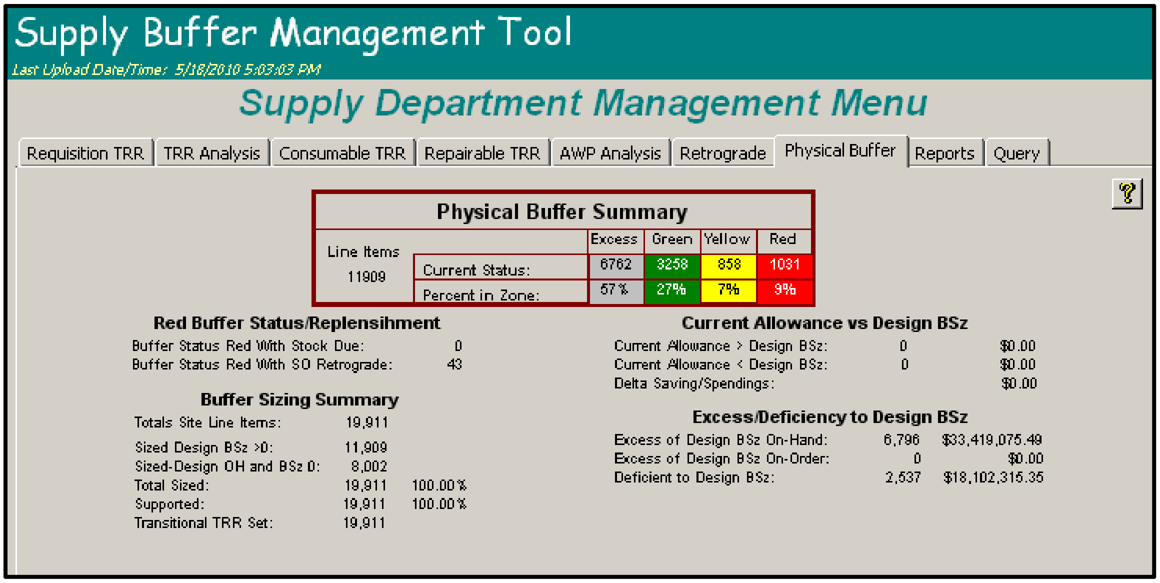

Figure 7. Supply Physical Buffer Summary. Adapted from NAVAIR (2011).

The Maintenance Department's reports are formatted similarly. The Department Summary examines backlog and physical buffer impact of inductions, as seen in Figure 8. Figure 9 is an example Awaiting Parts (AWP) report that summarizes how AWP MAFs are affecting the department's workload.

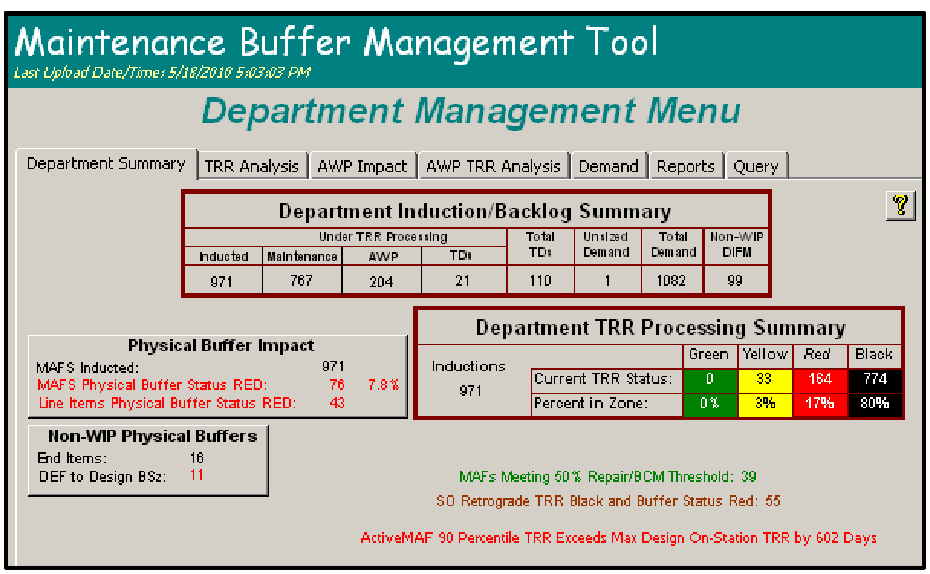

Figure 8. Maintenance Department Summary. Adapted from NAVAIR (2011).

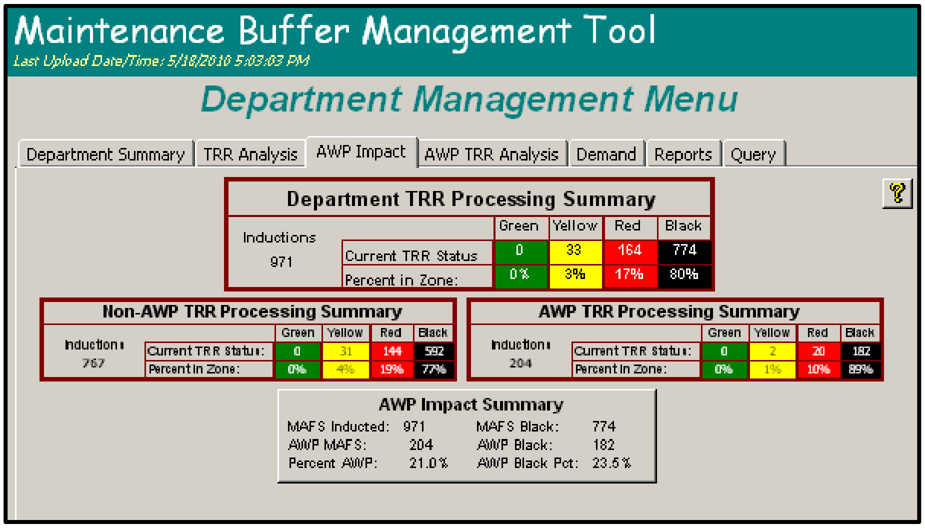

Figure 9. Maintenance AWP Impact Summary.
Adapted from NAVAIR (2011).

E. NALCOMIS

The Naval Aviation Logistics Command Management Information System (NALCOMIS) is the software program that manages maintenance activity in both Organizational and Intermediate level maintenance. The NALCOMIS system has two different versions, one optimized for the Intermediate level (I-Level) maintenance and one optimized for the Organizational level (O-Level) maintenance (primarily incorporating maintenance action forms linked to specific flight line aircraft).

NALCOMIS is a tool intended to help maintenance managers prioritize and manage their workload. There are two primary reports that are built into NALCOMIS at the I-Level. They are the Daily Production Report and the Production Report.

The NAMP states that the Daily Production Report "should be run and distributed on a daily basis. The Daily Production Report Part 2 provides a count of all maintenance actions accomplished from the begin date/time to the end date/time as selected by the user" (Department of the Navy, 2012, p. 14-19). This Daily Production Report is an overview of maintenance actions that have been completed. Managers can use this information to examine the current status of any Maintenance Action Form (MAF) for their work center or division.

The NAMP states that the Production Report should also be run on a daily basis. This report is more detailed, providing more detail about work stoppages due to awaiting parts (AWP) or if a part is deemed beyond the capability of maintenance that the work center can provide (BCM). This report "provides a snapshot of each work center's production with the number of components and status in the maintenance cycle (including OH, AWP, RFI, BCM, and backlog) within a specified begin and end date. A percentage of RFI/BCM rate is computed, showing work load production by work center" (Department of the Navy, 2012, p. 14-19).

F. R-SUPPLY

R-Supply is Aviation Supply's primary software program that provides online inventory, logistics, and financial management tools to the Aviation Supply Department. A wealth of data is contained in this program. While various measurements can be obtained on every part and requisition in the supply system, the performance metrics most used by the Aviation Supply Department are Net Supply Effectiveness and Gross Supply Effectiveness.

Net Supply Effectiveness is the proportion of requisitions filled of items that are carried on the supply shelf (Seagren, 2013). If a requisition is placed for an item that is not carried on the Supply Officer's shelf then it is not considered in this equation. Gross Supply Effectiveness, however, includes those items that are not carried on the supply shelf and is thus the proportion of requisitions filled to total requisitions (2013).

R-Supply produces two reports that contain these metrics as well as others: the Depth Effectiveness report and the Logistics Replenishment (LOGREP) Supply Effectiveness report. The Depth Effectiveness "produces a summary of the total customer demands, total issues, and the effectiveness expressed in a percentage" (NAVSUP P-732, 2005, p. 48). The LOGREP Supply Effectiveness report "produces a report that measures the supplying activity's ability to fill customers' requisitions and referrals (frequencies). The report summarizes the total number of customer demands, total issues, and the effectiveness expressed as a percentage by cognizance symbol within MIC" (NAVSUP P-732, 2005, p. 48).

G. SUPPLY RESPONSE METRICS

The NAMP describes several basic concepts and guidelines for I-Level maintenance in regard to material management. These include having standardized requisitioning procedures, maintaining positive control of all accountable material, maximizing use of personnel and material resources, and ensuring supply response to material demands is optimum (Department of the Navy, 2012). Ensuring supply response to material demands is particularly important in the discussion of performance metrics.

The NAMP dictates the response time goals the Supply Department should strive to achieve, determined by the priority of the part requisitioned. Priorities 1, 2, and 3 are given to all requisitions with Priority 1 being the most important. It is assigned to parts that are required for maintenance on an aircraft that is non-mission capable. Specifically, the absence of these parts renders an aircraft non-mission capable. The response time goals for these aircraft are as follows:

Table 1. Supply Response Time Goals

Issue Priority Group	Priority Designator	Processing Time
1	1–3	1 Hour
2	4–8	2 Hours
3	9–15	24 Hours

It is primarily the Aviation Supply Officer’s responsibility to ensure response times are being measured and reduced (Department of the Navy, 2012, p. 9-17). Each priority group has a goal processing time in which the requisition is to be filled and delivered to the squadron.

The NAMP states that one of the primary goals of the maintenance and supply personnel at all echelons is to reduce response time. It goes on to state that “the [turnaround time] of repairables must be improved through better control and reporting procedures” (Department of the Navy, 2012, p. 5-28). To monitor this performance, a

supply response time (SRT) metric is taken that indicates what percentage of requisitions are delivered within their target time.

H. AIRSPEED

The Naval Aviation Enterprise (NAE) officially implemented a program called AIRSpeed in pursuit of increasing fleet readiness in a cost-wise manner. The overarching methodologies of AIRSpeed are the Theory of Constraints, Lean Manufacturing, and Six Sigma. AIRSpeed is Naval Aviation's catalyst for continuous process improvement (CPI) within aircraft maintenance and aviation supply functions. It "provides a structured approach to plan, train, integrate, sustain, and monitor best business practices across the NAE. Functions include benchmarking, analysis, innovation, progress assessment, communications, and incorporation of best practices to maximize overall benefits" (Department of the Navy, 2012, p. 1-7). The NAMP identifies six fundamental principles of the AIRSpeed program (p. 1-7):

- Reduce Total Ownership Cost
- Manage aviation maintenance practices to maximize aircraft availability
- Identify and reduce non value added process steps (waste)
- Manage inventory and investments (parts, equipment, and facilities)
- Manage and reduce the variability in processes
- Create a culture of CPI

Each MALS has a dedicated AIRSpeed office. This office is designed to be led by an AIRSpeed officer with a minimum of three other personnel. This team will consist of at least two Green Belt-certified personnel and one Black Belt-trained individual. Furthermore, each division within the MALS is to have two Green Belt certified personnel.

The AIRSpeed office offers Yellow Belt and Green Belt Lean Six Sigma training. The trainees are then encouraged to return to their divisions to implement process improvement events. Identification of projects can happen in various ways. Most often, Marines recognize areas for improvement in their own divisions simply by being subject

matter experts and knowing what is and is not working. They experience the constraints on a day-to-day basis. The AMO has a high-level view of the maintenance department and is able to identify problems that affect multiple divisions or departments. The enterprise project alignment tool (EPAT) is another way that projects are identified.

The EPAT is used by an AIRSpeed office to focus its efforts. It "translates strategic level objectives to tactical goals and tasks" (NAVAIR 6.7.2.1, 2013, p. G-12). Within the EPAT, there are three primary documents: goal alignment chart (GAC), site opportunity worksheet (SOW), and tracking matrix (TM). The example EPAT in Figure 10 demonstrates the interaction of various organizations' goal and objectives.

The GAC is a command-level document that identifies process improvement opportunities that are aligned with strategic goals. The SOW is the AIRSpeed officer's tool for tracking projects that will help meet the strategic goals. The TM is the tool that portrays project progress as well as how the AIRSpeed projects are aligned with NAE objectives, command goals, and department goals.

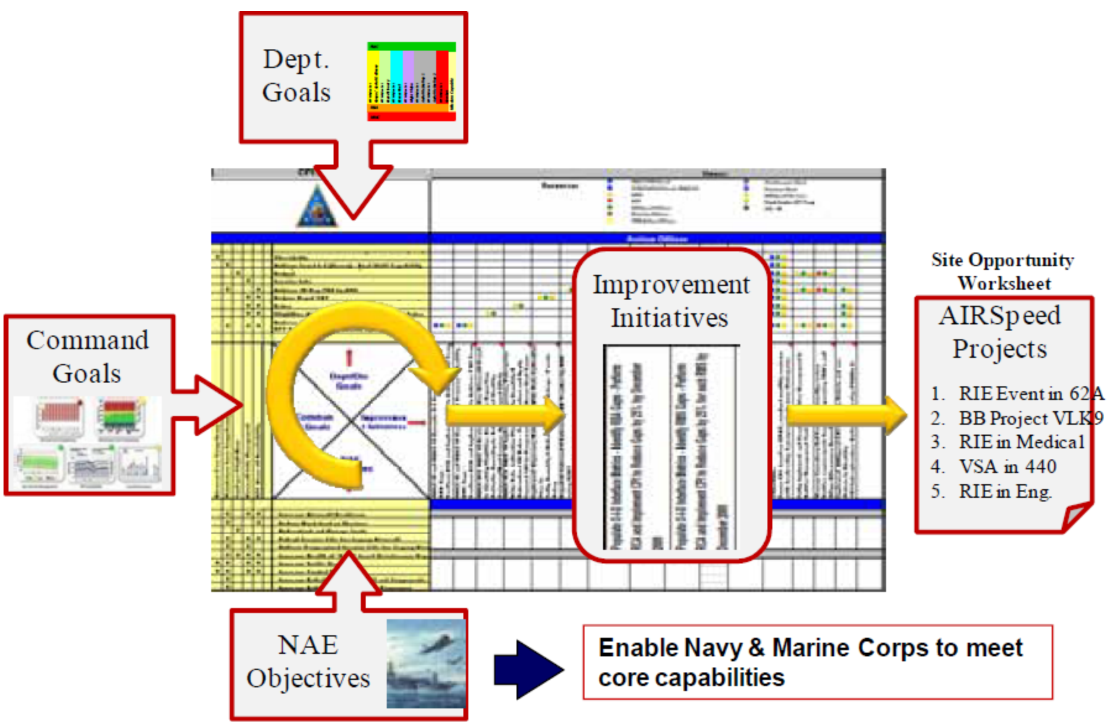

Figure 10. Example Project Alignment Tool
Source: NAVAIR 6.7.2.1 (2013).

I. CURRENT READINESS

The Marine Corps' Current Readiness program is a division of the Naval Aviation Enterprise (NAE) tasked to "to improve the delivery of combat ready forces to meet current and future operational requirements at an optimal Operating and Support (O&S) cost" (Naval Aviation Enterprise, n.d.). The Current Readiness program spans the entire system of Naval Aviation. The metrics used in this program inform Naval Aviation leaders of the current standing of a T/M/S fleet in terms of readiness, performance, and competency.

Some of the key metrics used are Aircrew Core Competency, Maintainer Core Competency, Aircraft Availability, and Cost per Flight Hour. These metrics are separated per T/M/S and examined at a "per squadron" level as well as a "total fleet" level. All of these metrics are in relation to a respective achievement target.

The Current Readiness program also examines cost and schedule performance of the T/M/S fleet, using popular Earned Value Management principles. The cost performance index is calculated based on planned versus actual total cost of contracts, fuel, repairables, and consumables. The schedule performance index is calculated based on the flight hours programmed versus actually flown for a given fiscal year. The actual cost in relation to the actual executed flight hours provides the Current Readiness with an Execution Index.

If the Execution Index is above or below a certain threshold, leaders dig deeper into the root cause of the variation. A cycle of briefs occurs throughout the year that spans the entire chain of command in Naval Aviation. These briefs are a collaborative effort of all levels in Navy and Marine aviation to address the root cause of problems that are negatively affecting readiness or costs in the fleet.

J. DOD SUPPLY CHAIN IMPLEMENTATION GUIDE

In 2000, the Logistics Management Institute (LMI) developed the Department of Defense (DOD) Supply Chain Management Implementation Guide. This report acknowledges "the lack of correct and comprehensive supply chain metrics in DOD" (Logistics Management Institute, 2000). It goes on to suggest that many of the metrics

used in supply chain management are financial or accounting measures inappropriately applied to supply chain manamagement. This is evidenced by “a consensus in DOD [that] considers the metrics currently available to senior DOD managers to be inadequate or lacking the depth to measure effectivenes and efficiency across the DOD supply chain” (Logistics Management Institute, 2000, p. 30). LMI suggests, therefore, that supply chains be measured on the basis of ten service quality factors: tangibles, reliability, responsiveness, competence, courtesy, credibility, security, access, communication, and understanding the customer.

Balestreri and McDoniel apply LMI’s strategy to supply chain management to a MALS by adapting the Supply-Chain Operations Reference model (SCOR), a performance measurement system popular in civilian industry. They defined the overall goal of AVLOG to be aircraft readiness (Balestreri & McDoniel, 2002). A MALS is only one factor of many that can enable a flight line squadron to increase aircraft readiness, however. Therefore, they conclude that inventory management and production management are the “primary critical success factors” for contributing to aircraft readiness and “logistics responsiveness and material availability [are] key conditions for achieving success” (Balestreri & McDoniel, 2002, p.83).

> Logistics Responsiveness was simply expeditiously delivering parts to the customer when requested, and material availability was comprised of 1) ensuring at least one part was available for issue off the shelf and 2) reducing DIFM material (due-in-from-maintenance 84 or work in process inventory)…These concepts follow the adapted SCOR logistic performance metrics of Supply Chain Response Time and Perfect Order Fulfillment. (Balestreri & McDoniel, 2002, p. 84)

They state that logistics response time (LRT) and customer wait time (CWT) are “the most significant metrics the MALS can utilize to improve aircraft Ao with respect to responsiveness” (p. 87). Balestreri and McDoniel define LRT for the MALS as “the total average time spent on-station from initiation of a squadron’s requisition to the delivery and completion of that requisition,” and they define CWT as “the total average [time] spent processing customer’s requisition on-station and ultimately satisfying that requisition from off-station or upstream members of the Naval/Marine Corps aviation logistics supply chain” (p. 86). Succinctly, LRT is the amount of time a requisition

spends on-station and CWT is the time spent off-station. The combination of these times is the Supply Chain Response Time.

An additional metric they emphasize is perfect order fulfillment, defined as “the ratio of perfectly satisfied orders to all orders measured” (p. 93). This is generally equivalent to a common fill rate metric used in industry sectors. The metric reflects material availability as a success factor in contributing to aircraft readinesss.

Perfect order fulfillment and supply chain response time are two metrics that, when optimized, will contribute to increased aircraft readiness, the goal of AVLOG. Balestreri and McDoniel conclude that “perfect order fulfillment and supply chain response time must be integrated throughout not only the MALS, but also throughout the entire Naval/Marine Corps aviation logistics supply chain. Utilizing these two performance metrics throughout the entire enterprise will focus all members of the supply chain on the common goal of aircraft readiness” (p. 112).

K. CHAPTER SUMMARY

The nodal logistics laydown structure of MALSP MOD requires that all members in the logistics chain are working toward the same goal in order to be successful. To measure the progress toward that goal, data management systems such as BMT, NALCOMIS, and RSUPPLY have been established to document and measure the major functions of the MALS. Programs such as AIRSpeed and Current Readiness have been established to improve processes and appropriately allocate resources from a systematic level. These systems and programs are established to align all of AVLOG to the common goal of sustaining aircraft readiness at a high enough level to enable aircrew to achieve and maintain appropriate competencies.

III. LITERATURE REVIEW

A. INTRODUCTION

This chapter discusses current measurement systems that are considered best business practices in the industry realm. It also discusses two different approaches to performance measurement adopted by the Air Force and the Navy submarine fleet. An understanding of these performance measurement systems will aid in the discussion of what may and may not be applicable to a MALS.

A popular adage among military and business professionals states what you measure is what you will get. “Inspect what you expect” is a version of this concept often repeated in the Marine Corps. Eliyahu Goldratt, who popularized the theory of constraints management principle, wrote, “Tell me how you measure me, and I will tell you how I will behave” (Goldratt, 1990, p. 26). The link between measurements and performance has led to the creation of many measurement systems in both civilian and military organizations. This literature review examines logistics and supply chain performance measurements and their use among civilian and military organizations.

B. METRICS AND MEASUREMENT SYSTEMS

There is a necessary distinction to be made between performance metrics and performance measurement systems. Managers may easily make the mistake of assigning a single performance metric as their performance measurement system, using an individual part to be indicative of the whole. A performance metric, however, is a metric used within a performance measurement system and largely focuses on measuring individual processes (Caplice & Sheffi, 1994).

Logistics does not consist of a singular activity, however, and thus a singular measurement is insufficient to measure a system’s performance. Logistics “encompasses a complex set of activities which require a collection of metrics to adequately measure performance” (Caplice & Sheffi, 1995, p. 61). A performance measurement system is built upon performance metrics.

Not all performance metrics and performance measurement systems are helpful, however. Caplice and Sheffi provide separate criteria for evaluating performance metrics and performance measurement systems. The eight criteria for evaluating individual logistic performance metrics are defined in Table 2.

Table 2. Eight Performance Metric Evaluation Criteria. Adapted from Caplice and Sheffi (1994).

Performance Metric Evaluation Criteria Summary	
Criteria	**Description**
Validity	The metric accurately captures the events and activities being measured and controls for any exogenous factors.
Robustness	The metric is interpreted similarly by the users, is comparable across time, location, & organizations, and is repeatable.
Usefulness	The metric is readily understandable by the decision maker and provides a guide for action to be taken.
Integration	The metric includes all relevant aspects of the process and promotes coordination across functions and divisions.
Economy	The benefits of using the metric outweigh the costs of data collection, analysis, and reporting.
Compatibility	The metric is compatible with the existing information, material, and cash flows and systems in the organization.
Level of Detail	The metric provides a sufficient degree of granularity or aggregation for the user.
Behavioral Soundness	The metric minimizes incentives for counter-productive acts or game-playing and is presented in useful form.

Not all performance measurement systems are equally helpful, either. The system can be "well designed at the strategic level [but] can be flawed at the individual metric level" (Caplice & Sheffi, 1994, p. 11). Six evaluation criteria for performance measurement systems are shown in Table 3. Crafting performance measurement systems according to these criteria will help ensure the resulting actions of those measured by the system will best benefit the organization and its customers.

Table 3. Six Performance Measurement System Criteria. Adapted from Caplice and Sheffi (1995).

Performance Measurement System Evaluation Criteria Summary	
Criteria	Description
Comprehensive	The measurement system captures all relevant constituencies and stakeholders for the process.
Causally Oriented	The measurement system tracks those activities and indicators that influence future, as well as current, performance.
Vertically Integrated	The measurement system translates the overall firm strategy to all decision makers within the organization and is connected to the proper reward system.
Horizontally Integrated	The measurement system includes all pertinent activities, functions, and departments along the process.
Internally Comparable	The measurement system recognizes and allows for tradeoffs between the different dimensions of performance.
Useful	The measurement system is readily understandable by the decision makers and provides a guide for action to be taken.

No organization can excel completely in all criteria, whether for performance metrics or performance measurement systems. Necessary tradeoffs must be made among the metric criteria. The integration and usefulness criteria, for example, face a necessary trade-off between scope and span of control (Caplice & Sheffi, 1994). Additionally, as a metric becomes more robust, it allows for more comparability between organizations or units. However, this negatively impacts its validity as it has to be less specific to an organization.

The goal of a metric is to be indicative of the level of performance of an individual process. The goal of a measurement system, however, is to “guide and influence the decision making process” (Caplice & Sheffi, 1995, p. 65). In order properly affect decision makers, a performance measurement system ought to be developed in terms of output and the customer.

Regarding output, “the basic transaction [for logistics] is a completed delivery to a customer” (1995, p. 65). The output (i.e., completed deliveries) and the customer are to be the focal points of a performance measurement system because the output is a result of

all processes within an organization and the delivery to a customer is the extent to which a logistics system has influence. A diagram illustrating how a system's output is a function of individual processes is seen in Figure 11.

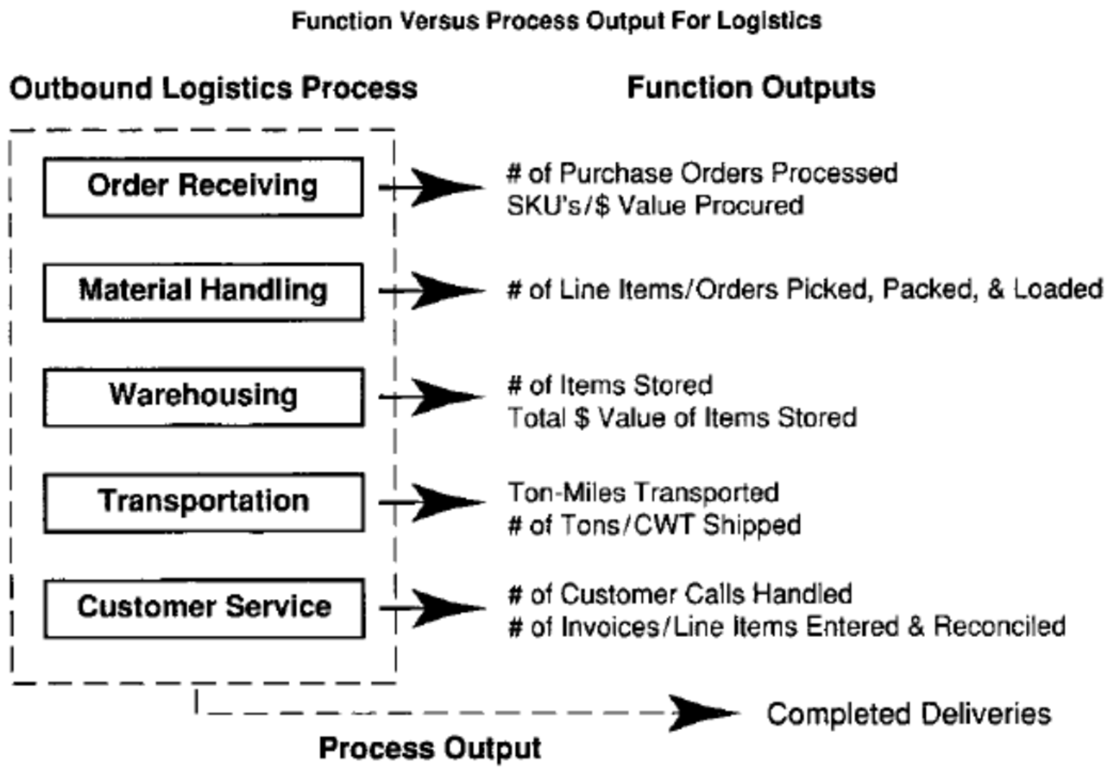

Figure 11. Process Output as a Product of Function Outputs.
Source: Caplice and Sheffi (1995).

C. COMMON PERFORMANCE MEASUREMENT SYSTEMS

Popular measures of performance in the civilian industry realm include the Supply Chain Measurement System (SCM), Balanced Scorecard, Economic Value Added (EVA), Process-Based Measurement, and Supply-Chain Operations Reference model (SCOR). Companies adopt and adapt these systems to create a customized fit for their organization that meets their specific needs.

Piotrowicz and Cuthbertson (2014) surveyed 51 international companies regarding the metrics they use, the factors that influence those metrics, and their perceived importance to the organization. These companies described their core activities

as manufacturing, retail/wholesaling, transport, logistics value added, warehousing, or some combination thereof. Of these companies, the performance measurement systems used most often were the Balanced Scorecard (19 companies), Process-Based Measurement (15 companies), and SCOR model (12 companies).

The Balanced Scorecard was developed by Kaplan and Norton (1992) to be “a set of measures that gives top managers a fast but comprehensive view of the business” (p. 71). It provides insight into the performance of an organization through four difference perspectives: customer perspective, internal perspective, innovation and learning perspective, and financial perspective. As seen in Figure 12, Balanced Scorecard seeks to focus an organization on overarching goals and strategy while traditional measurement systems focus on individual metrics. Traditional measurement systems may cause employees to work to optimize the metric rather than the goal it is meant to serve. The Balanced Scorecard focuses the whole organization on a unifying goal.

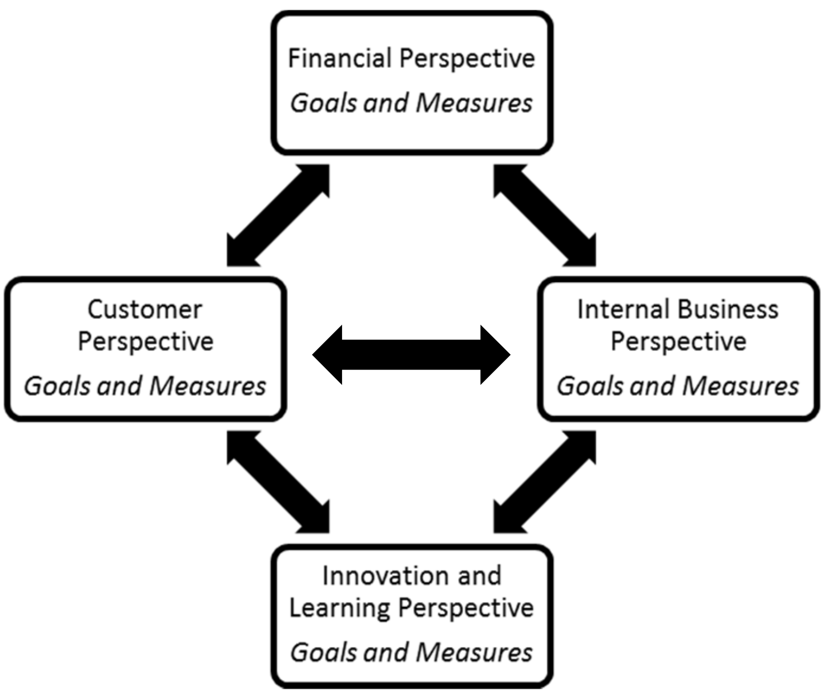

Figure 12. Balanced Scorecard Diagram. Adapted from Balanced Scorecard Institute (2015).

The Balanced Scorecard is helpful because the organization must define goals not only in terms of financial performance (which is easily measured and understood by stakeholders) but in other more intangible aspects of a corporation's performance. By setting goals in all four perspectives, a company must also determine measures that convey effectiveness in achieving those goals.

The third primary measurement system respondents used was the Process-Based Measurement system. It takes an analytical approach that focuses on the supply chain as a process divided into six main sections: supplier, inbound logistics, core manufacturer, outbound logistics, marketing and sales, and end customers (Chan & Qi, 2003). Processes are decomposed into core processes, sub-processes, and activities, driven by goals and defined in terms of responsibility and function, as shown in Figure 13. A primary advantage of a process-based measurement system is that it creates opportunity for continuous process improvement. The Balanced Scorecard focuses on prior performance and is not able to readily identify problems in the supply chain process. Process-based measurement utilizes a metric called Performance of Activity (POA). These measurements include tangible and intangible aspects of the process and include cost, time, capacity, capability, productivity, utilization, and outcome.

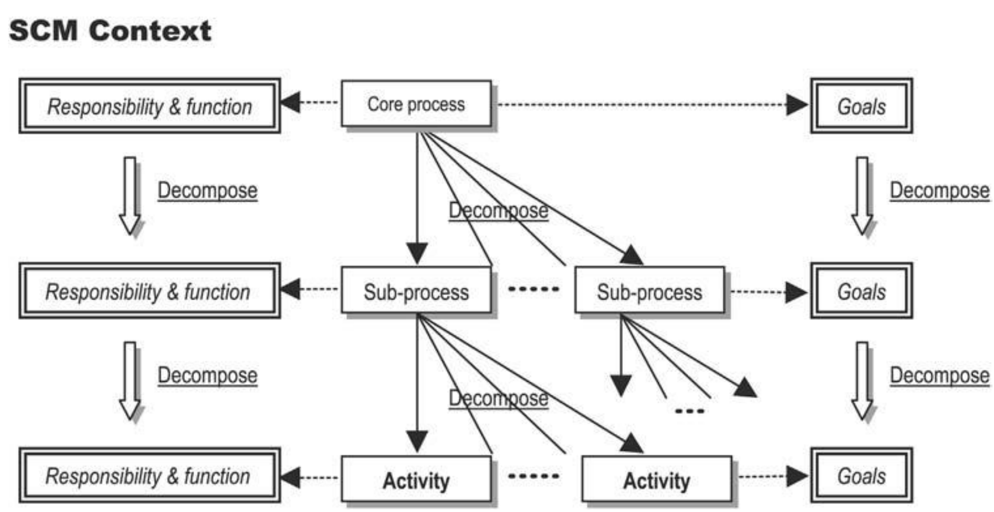

Figure 13. Process-Based Measurement System.
Source: Chan and Qi (2003).

The SCOR model is also a process focused measurement system but it focuses on four main processes: plan, source, make, and deliver. The model continues to break those four main categories into two more levels of sub-processes but those four functions are the primary focus, as seen in Figure 14. SCOR "spans interactions pertaining to customers/markets and transactions pertaining to products" (Khare, Saxsena, & Teeware, 2012, p. 29). While the SCOR model rated third in performance measurement systems by companies in the Piotrowicz study, specific SCOR metrics were used the most individually.

Figure 14. The SCOR® Model. Source: Defense Acquisition University (2012)

D. SCHEDULING AND DISPATCH RULES

Maintenance managers are continually faced with decisions about workload scheduling and which items should take priority for repair. Various methods exist, called dispatch rules, that aide decision makers in this task. Examples of popular dispatch rules include prioritizing jobs by shortest processing time, longest processing time, earliest due date, first-come-first-serve, and critical ratio (Baker & Trietsch, 2009, p. 359).

Dispatch rules are helpful for managers because they enable quick decision making for prioritizing jobs. Each time a job is completed, a new priority must be determined. If the dispatch rule of shortest processing time is followed, then the estimated processing times of all jobs are examined and priority goes to the job with the

shortest time. The inverse is true of the longest processing time. The earliest due date dispatch rule prioritizes jobs based upon their due date and disregards their estimated processing time (2009). A first-come-first-serve dispatch rule prioritizes jobs in the order in which they are received.

The critical ratio dispatch rule is a ratio of remaining allowance and remaining work. Baker and Trietsch state, “critical ratio priorities measure urgency by the ratio of remaining allowance and remaining work rather than their difference” (p. 359). Those with the smallest critical ratio receive priority while a ratio value of 1 indicates a job has the most work left to do but also the most time in which to do it.

E. SERVICE LEVEL

Service levels and fill rates are common metrics used in supply chain management to measure the effectiveness of an inventory management policy. Nahmias (2009) titles these metrics as Type 1 Service (also known as Service Level) and Type 2 Service (also known as Fill Rate). Service level is “the probability of not stocking out in the lead time” (p. 272). Fill rate is defined as “the proportion of demands that are met from stock” (p. 273).

The fill rate is a commonly used service metric and is generally what is meant when a manager speaks of service level (Nahmias, 2009). This metric is important for determining inventory policy in order to ensure a certain level of customer satisfaction is met. The cost to provide 100% satisfaction can often be too great for an organization to absorb so a certain level of risk must be accepted on behalf of an organization. The risk tolerance of an organization is generally determined by the cost of that risk.

For example, if a shortage cost is extremely high and a holding cost is extremely low, then it is easy for an organization to justify a high level of inventory in order to optimize customer satisfaction. If shortage costs are low and holding costs are high, it is easier to justify accepting more risk for the sake of optimizing financial performance.

F. LEAN SIX SIGMA AND THEORY OF CONSTRAINTS

Lean Six Sigma and the Theory of Constraints are not performance measurement systems but they are widely used within logistics and supply chain management. Their relationship with performance measurement is quite direct, however. The Theory of Constraints focuses on managing the constraints in a process in order to improve productivity. Lean methodology seeks to eliminate waste within a process and therefore reduce cycle time. Six Sigma is a statistical control process that focuses on reducing variation in a process that can be costly.

To implement any of these process improvement methodologies, one must define the goal of the process as well as determine how to measure that goal. Once that goal is defined, an organization can begin improving processes that specifically contribute to achieving that goal. The DMAIC model of process improvement (Define, Measure, Analyze, Improve, and Control) uses these methodologies to optimize a process according to a specific goal. One must define tolerances in a process in order to implement Six Sigma and one must define an overall measure of performance according to a goal in order to implement Theory of Constraints.

G. AIR FORCE

The Air Force Logistics Management Agency (AFLMA) and the Air Force Materiel Command (AFMC) both developed and recommended separate performance measurement systems for use by the Air Force. Leonard (2004) examined these two performance measurement systems and found that the AFMC system is modeled around four primary metrics: Aircraft Availability, Requirements Computation, Asset Allocation and Funding, and Real World Performance. The AFLMA focused rather on four core processes: Repair, Buy, Stockage and Distribution, and Funding.

AFLMA's performance measurement system espouses a Balanced Scorecard approach with six segments, as seen in Figure 15. These six segments have 23 assigned metrics in total measuring each segment's performance (Leonard, 2004).

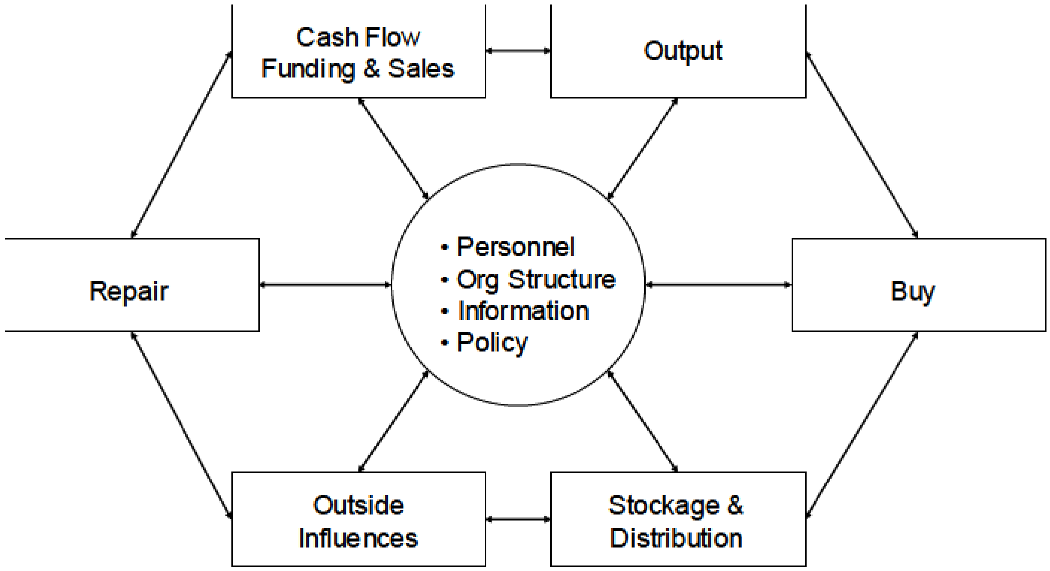

Figure 15. AFLMA's Balanced Scorecard.
Source: Leonard (2004).

The AFMC performance measurement system uses only ten metrics, five measuring performance and five measuring process, as depicted in Figure 16. The simplicity of this model may assist managers in the decision making process more so than AFLMA's measurement system of 23 metrics.

Real World	Aircraft Availability	Requirements Generation (D200)	Requirements Allocation —Financial Systems
Performance Measures		*Process Indicators*[1,2]	
Aircraft Availability		Total Requirements Variance	
MICAP Hours		Issue Effectiveness	
MICAP Incidents		Stockage Effectiveness	
Customer Wait Time (CWT)		Backorders	
Net Operating Results		Logistics Response Time (LRT)	

Figure 16. Collective Overview of AFMC’s Measurement System. Source: Leonard (2004).

H. NAVY SUBMARINE FLEET MAINTENANCE METRICS

The Navy created a Submarine Fleet Maintenance Metric Working Group (Working Group) tasked with developing various metrics to measure the performance of submarine Fleet Maintenance. The Working Group “took the perspective of viewing Fleet Maintenance as a complex system, with multiple stakeholders, executing a series of integrated processes” (Submarine Fleet Maintenance Metric Working Group, 2013, p. ii).

The systems approach enabled the Working Group to create an “integrated set of metrics that measure performance, productivity, planning, execution, finance, and backlog, while reducing the impact on the already limited bandwidth of those overseeing intermediate level maintenance” (Submarine Fleet Maintenance Metric Working Group, 2013, p. ii). This systemic view and the integration of metrics enables results in performance and productivity metrics that are positively and negatively affected by the more discrete metrics of which they consist.

The Working Group developed two primary metrics, a productivity metric and a performance metric. They generally define the productivity metric (PROD) as "output divided by input." It consists of four variables, demonstrated in Equation 1: routine maintenance (2K), periodic maintenance requirements (PMR), and alterations (ALTS), divided by the total direct cost (CTC) (Submarine Fleet Maintenance Metric Working Group, 2013).

$$Productivity = \frac{\sum(2K + PMR + ALTS)}{CTC}$$

Equation 1. Working Group Productivity Metric
Source: Submarine Fleet Maintenance Metric Working Group (2013)

The second primary metric the Working Group developed was the performance metric (PERF). It is defined as "the weighted sum of on-time delivery (TD), total direct cost (COST), planning event completion (PLNG), late work (LW), deferred work (DW), and backlog (BL) divided by the sum of the weights" (Submarine Fleet Maintenance Metric Working Group, 2013, p. 38). Mathematically, it is defined as:

$$Performance = \frac{.420TD + .222COST + .132PLNG + .082LW + .072DW + .072BL}{\sum_{i=1}^{6} w_i}$$

Equation 2. Working Group Performance Metric
Source: Submarine Fleet Maintenance Metric Working Group (2013)

The variables in PERF go beyond typical schedule and cost variables. Other variables were added that were considered highly important by the Working Group. The basic PERF metric was given several different varieties to better serve the concerns of different stakeholders in the system. For example, activities within the logistic system are affected differently by late work and therefore the PERF metric weights that variable differently to better capture the magnitudes by which late work affects their performance individually. The basic PERF metric format, however, is largely the same for each activity. The weights for each variable are assigned according to the opinions of the subject matter experts in the Working Group.

I. CHAPTER SUMMARY

Logistics metrics and performance measurement systems are not equivalent. For either of them to be useful to decision makers, they ought to sufficiently meet the criteria proposed by Caplice and Sheffi (1994). In recognition of the delineation between individual metrics and measurement systems, civilian industry has adopted several performance measurement systems. These systems provide holistic solutions to measure the key components of a business that contribute most directly to an organization's goal.

These systems, however, largely consist of certain financial metrics that are not directly applicable to many military organizations. Given these shortcomings, the Navy submarine maintenance fleet, for example, created a performance metric that met their specific needs. This performance metric assigns weights to key logistic metrics and reports the weighted average as a holistic measurement of performance.

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IV. ANALYSIS

A. INTRODUCTION

How one is measured influences how one behaves. This underlying idea is the foundation of this section. An organization must choose carefully which measurements it uses to determine how it is performing. These measurements, when emphasized, will influence an individual's behavior, the performance of an organization, and the strategy an organization adopts. This analysis section examines primary metrics currently used by a MALS and how they affect individuals, the organization, and the customer.

B. DEFINING THE GOAL OF A MALS

Balestreri and McDoniel (2002) may very well be correct in concluding that aircraft readiness is the goal of aviation logistics as a whole. However, defining this as the goal of a MALS, specifically, is problematic. There is an important disconnect between a MALS and aircraft readiness that must be recognized.

The performance of a MALS may directly contribute to aircraft readiness but it cannot solely *cause* aircraft readiness, though a well-perforing MALS is necessary for high aircraft readiness. If a MALS can solely cause aircraft readiness then an optimized, perfectly performing MALS in ideal conditions would result in perfect aircraft readiness among the flightline squadrons it supports. This, however, is not the case. An optimized MALS will result in RFI parts being delivered to flight line squadrons as soon as they are needed by those squadrons, enabling though squadrons to achieve aircraft readiness. That is the extent of the output of a MALS.

MALS certainly performs more functions for flight-line squadrons than delivering RFI parts. MALS Marines may conduct nondestructive inspections (NDI) of helicopter blades or other airframe components. They may help troubleshoot low power on an engine. There are many functions a MALS serves for their flight line squadrons but the vast majority of them, in some sense, result in an RFI part being delivered for a part being deemed RFI. Determining a blade is safe for flight through an NDI is a form of

rendering the potentially non-RFI blade as, in fact, RFI. Helping troubleshoot low power engines and bringing them up to normal power is a form of making that engine RFI.

The MALS's extent of influence on readiness in a flight line squadron ends once the ready-for-issue (RFI) part is delivered to the flight line squadron. The squadron must then install the part, the correctly installed part must actually solve the discrepancy for which the part was ordered, and, depending on the level of maintenance performed, the mainteners and aircrew may need to successfully perform a functional check flight. Only then will that aircraft be able to contribute to an increase aircraft readiness. The goal of aviation logistics as a whole may be to increase aircraft readiness but that is beyond the scope of a MALS.

While a MALS has many functions and responsibilities (i.e., maintenance on repairable components, inventory management, supply chain management, supporting squadron detachments and deployments, training Marines, ensuring the welfare of Marines and their families), the ultimate goal of a MALS is to provide ready-for-issue (RFI) parts to flight line squadrons. An organization has many responsibilities that do not contribute to achieving its goal but those responsibilities must not be misunderstood as that organization's goal. The Marine Corps, for example, has not established a MALS in Hawaii in order to train maintenance Marines. That is merely one of its responsibilities. A MALS exists in Hawaii to best support the flight line squadrons there with the parts that they need.

The goal of the MALS must not be confused with its various responsibilties. Further, the goal of the MALS cannot exceed the end point of the supply chain process that it is able to control. That end point is when an RFI part is delivered to the squadron or an I-Level maintainer is able to sign off a MAF submitted to the MALS from a squadron. The goal of the MALS, therefore, is the output of its functions—specifically, RFI parts.

C. DEFINING A GOOD METRIC

Currently, a MALS has metrics measuring its many individual functions or processes. Identifying an overarching performance measurement system is much more

difficult. For example, the Buffer Management Tool, discussed in this chapter, best manages pertinent information and measurements of primary functions in a MALS, yet it is not necessarily used as a performance measurement system. Rather, individual data process measurements from the BMT are most commonly captured and analyzed.

MALS performance as a whole ought not to be measured solely in terms of TRR, BCM rates, or any other individual metric. These metrics may be important for internal analysis but they do not reflect the level of success a MALS has in obtaining its goal. For example, black MAFs in regard to Design TRR are a maintenance specific metric whereas Supply Effectiveness is a supply focused metric (it is affected by maintenance performance but that is not the focus of the metric). This does not mean, however, that these metrics are to be disregarded. It simply means these metrics are indicative of internal process performance only.

Caplice and Sheffi (1994) do not necessarily distinguish between criteria that make good logistics metrics and criteria that make good performance measurement systems. The distinction is necessary because the purposes of each are different. A logistics metric is internally focused, examining the efficiency or productivity of a process. A performance measurement system examines the overall system’s ability to produce its output, understood in terms of a product or service for a customer. A performance measurement system has broader managerial implications than a logistics metric.

Caplice and Sheffi’s criteria for performance metrics and performance measurement systems, summarily given in Table 4, are used as the criteria for this evaluation of metrics currently used by MALS to measure performance. A MALS has no standard performance measurement system and thus the metric criteria, rather than the measurement system criteria, underlie the evaluation of current MALS metrics.

Table 4. Summary of Criteria

Metric Criteria	Measurement System Criteria
Validity	Comprehensive
Robustness	Causally Oriented
Usefulness	Vertically Integrated
Integration	Horizontally Integrated
Economy	Internally Comparable
Compatibility	Useful
Level of Detail	
Behavioral Soundness	

D. MEASUREMENTS AND PERFORMANCE

Performance metrics influence the actions of Marines within a MALS in particular ways. These actions contribute to a certain level of respective performance for the MALS as a whole. This section examines how MALS performance is impacted by using these metrics. More specifically, this section examines the resulting effects that flight line squadrons experience as a result of optimizing respective metrics. Optimizing the metric, in this context, refers to the MALS using its resources to improve the activity that the metric measures.

1. Buffer Management Tool—Buffer Status

The Buffer Management Tool (BMT) is not a metric in and of itself. It does, however, provide a wealth of analytical data that is useful for the user. Many metrics a MALS uses are pulled from the BMT. One metric in particular that the BMT produces that is used frequently (daily) and widely within the MALS maintenance department is Buffer Status. Another is TRR.

The Time to Reliably Replenish (TRR) measures the amount of time a part has spent being repaired in relation to the expected amount of time to repair that part. This is primarily understood in this context as a maintenance metric. The second metric is a part’s physical buffer status and it refers to the physical inventory level of that part on the

ASO's supply shelf. These metrics are often reported in terms of how many black or red MAFs there are currently.

The BMT organizes Maintenance Action Forms (MAFs) by the time projected to complete, or sign-off, the MAF. Once a repairable part comes to the MALS for repair, a MAF is initiated. This MAF documents the current status of the repair. The status may range from being In-Work (IW) to Awaiting Parts (AWP). A myriad of other status codes exist but explanation of them does not contribute to the current discussion.

While the BMT provides a wealth of information regarding the status of each MAF and each part on the shelf, certain metrics are used most often to manage the workload. For the Supply Department, these include the Requisition TRR, Consumable TRR, Repairable TRR, and Physical Buffer Status. These show what is the current TRR versus Design TRR of parts as well as how many parts have a physical buffer status of red. For the Maintenance Department, these include backlog and physical buffer impact of inductions as well as Awaiting Parts (AWP) Impact reports. These show how their workload is impacting the physical buffer status and how much of it is due to maintenance delays rather than awaiting parts from supply.

The purpose of the BMT is to help maintenance managers better prioritize their workload. According to the NAE CPI Guidebook:

> BMT was initially created to provide Intermediate Maintenance Activities (I-Level) the insight necessary to analyze and understand the demand placed on their production and to help understand their ability to meet that demand while revealing the time it actually takes them to reliably repair (or replenish) the asset to ready for issue (RFI). BMT provides the ability to see constraints in the production system and to make decisions where to best concentrate CPI activities to improve production capability (Time to Reliably Replenish or *TRR*) where it will have the greatest impact. (NAVAIR 6.7.2.1, 2013, p. 6-8)

To accomplish this task, the BMT color codes each MAF according to the benchmarked time to repair that part, the TRR. The NAE CPI Guidebook (2013) explains how each color code should be prioritized (p. 6-14). For example, any MAF with a physical buffer status of red should be worked first and in accordance with the TRR. If a part has a benchmark of 30 days for repair, it is expected to take 30 days to repair that

part. During days 21-30, the MAF has a color code of red. Red MAFs should be worked first, in a “first in, first served” manner. During days 11–20, the MAF has a color code of yellow. If a MAF is yellow, work should only take place if there is a stoppage on all red MAFs. During days 1–10, this MAF has a color code of green. During the green phase, work on this repairable should only commence after there is work stoppage on all yellow and red MAFs. After day 30, the MAF has a color code of black. Black MAFs, the guidebook explains, should only be worked on after red, yellow, and green MAFs are unavailable for further work. These black MAFs should be prioritized according to the ASO’s physical buffer needs.

The reliability of the benchmark, or the Design TRR, for each repairable is therefore critical to how beneficial the BMT is. The process a MALS generally takes to set repair time benchmarks is quite cumbersome and potentially inaccurate. To set a benchmark for a part, a work center within a division will designate a “Design Team” to analyze the repair process and determine a reasonable estimation of the repair time for that part. To do so, it chooses the repairable part and track the time of every step required to complete the repair on that part. That repair time is then set as the Design TRR, or benchmark, for that repairable.

Using a sample size of one cannot produce a reliable benchmark, however. In order to mitigate this, work centers will generally deduct from the total time any steps that take unusually long. The evaluation of these steps as potential outliers is based on the knowledge of subject matter experts on the Design Team. While this may improve the reliability of that repair time as representative of population, it still falls short of providing a reliable sample.

To further cloud the problem, parts are often grouped together and assigned the benchmark of just one of the analyzed parts. This is done because an individual MALS has hundreds, potentially thousands, of parts that it repairs. The process used to benchmark one individual repairable is time consuming and obligates valuable man-hours. To do this repeatedly for each repairable would severely impair the maintenance department.

When determining parts to be grouped together for the same TRR assignment, work centers will often choose a repairable that is generally representative of the typical repair process for parts in that work center. The benchmark for the individual part is then applied as the benchmark for a group of parts. This group of parts could be all parts a work center repairs or groups of similar parts a work center repairs.

Grouping parts together and assigning them all one single TRR for maintenance is inherently problematic, however. To illustrate this, consider a notional but reasonably realistic example of a work center that repairs composite main and tail rotor blades for two different types of helicopters. These four different types of blades have different part numbers and each blade has a multitude of types of repairs that may be required. Each blade can only be assigned one TRR and this TRR does not change with different types of repairs. Given the nature of composite repair and parts availability for Marine Corps rotor blades, some repairs may take days while some take weeks.

Prioritization of the maintenance workload is based on the physical buffer status of an item and the time buffer of an item, its TRR. If the physical buffer status on two items repaired by the same shop is equal, the one with the shortest TRR will take priority if shortest processing time is the shop’s dispatch rule. If these are high priority parts, then the estimated TRR is also communicated to the AMO, ASO, and requisitioning squadron for other planning purposes. If the repair is estimated to take so long that it impairs readiness at the squadron, the AMO and ASO may seek an alternate solution to obtaining an RFI part. In the example of repair times for rotor blade repair, cannibalization of blades or lateral support requests are based upon the maintenance TRR of the item.

Using four different rotor blades as an example, notional minimum and maximum total delay time of each rotor blade are demonstrated in Table 5. The 90th percentile of each blade’s repair time distribution is its TRR. Specifically, this means that 90% of the time, this blade will be repaired in that number of days or fewer. Using an average of repair distributions is a common way to assign multiple parts a single TRR. In this example, 21.58 days is the average of all the blades’ repair distributions. The cumulative density function (CDF) indicates the total probability of repairing that blade in a time frame less than or equal to 21.58 days . The 90th percentile and averaged TRR of all parts

was simulated using Crystal Ball. Beta distributions of repair times for each blade were assumed and 100,000 trials were run per simulation.

Table 5. Repair times for Notional Parts, TRR at 90th Percentile, and CDF of Each Part if Assigned Averaged 90th Percentile.

	Min Repair (Days)	Max Repair (Days)	90% (TRR)	CDF at 21.58 days
Blade A	3	45	31.58	60.787
Blade B	2	25	17.63	99.045
Blade C	1	15	10.5	100.000
Blade D	5	65	45.7	31.341

A forecast was modeled for each variable individually and a fifth forecast was modeled of the average of the four variables. The 90th percentile of each blade's individual forecast is demonstrated in Table 5. The 90th percentile of the averaged forecast was 21.58 days. If 21.58 days is applied to each blade as the TRR, managing the maintenance workload based on TRR becomes problematic. Two of the blades will consistently exceed its TRR and two will consistently finish before its TRR. One can see in Figure 17 that Blade C will always meet its TRR while Blade D will only meet its TRR 31% of the time. If any one of the TRRs is applied to all blades, rather than averaging the forecasts, the results are no more helpful.

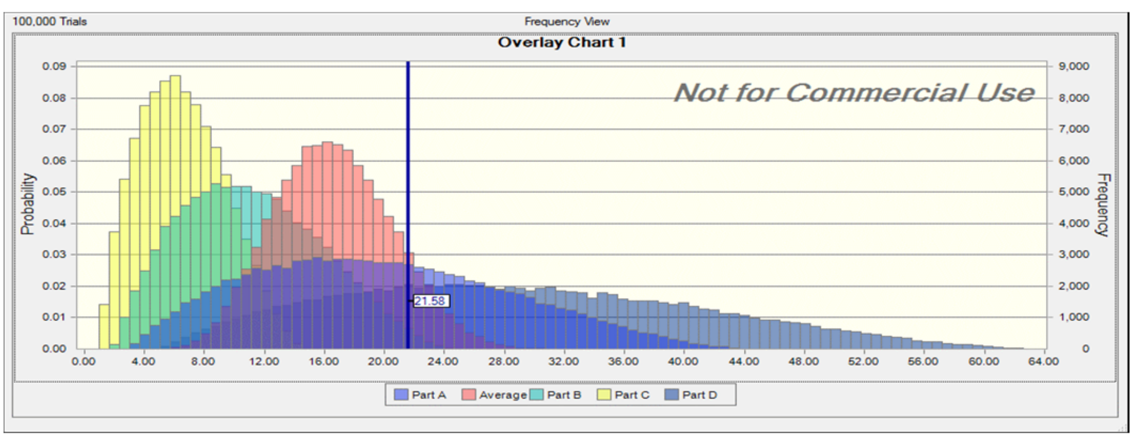

Figure 17. Forecast Blade Repair Time Distributions and Average.

There is no hard requirement for work centers to ensure the accuracy of their benchmarks. According to the NAMP, the MALS ought to utilize the AIRSpeed team to "conduct value stream mapping and analysis to benchmark existing processes and illustrate improvement opportunities" (Department of the Navy, 2012, p. 3-55). This is the only requirement for developing benchmarks for repair processes. Ensuring these benchmarks are updated and reasonable is only implied at best and left to the responsibility of the AIRSpeed team.

If a MALS optimizes the buffer status metric produced by the BMT, the resulting goal is to reduce buffer status red parts on the supply shelf. In order to reduce buffer status red parts, the maintenance department will prioritize all MAFs for parts that are red-coded for supply. Red-coded MAFs will always be worked first, followed by yellow and then green. Any MAFs that have exceeded their TRR are coded black for maintenance will be worked into the red-yellow-green rotation of MAF prioritization.

To effectively manage the workload in this way, Design TRR estimates need to be reliable and specific to each part. Design TRR numbers need to be established for each part individually and updated as processes or capabilities change. Otherwise certain parts may always exceed their TRR and be consistently coded black. A maintenance manager will typically follow a specific dispatch rule, whether explicitly stated or not. If reducing red physical buffer status MAFs is the priority of the MALS, a shortest processing time dispatch rule may be adhered to. If multiple parts are assigned a non-specific Design TRR, a part may be inordinately prioritized.

As holes get filled on the supply officer's shelf (i.e., buffer status red parts are repaired and replenished), the squadron has an increased number of requisitions filled immediately, rather than be coded as not-in-stock. This means squadrons are both receiving parts and resuming work on aircraft more quickly. The MALS' focus on filling holes in the supply shelf positively affects its fill rate.

2. Time to Reliably Replenish—TRR

The Time to Reliably Replenish metric is directly related to the previous discussion regarding the Buffer Management Tool. It can also be used as standalone

metric, however. According to the NAMP, TRR is generally defined as “the time, in hours or days, it takes once a part is pulled from the supply shelf until it is back on the supply shelf ready for issue” (Department of the Navy, 2012, p. A-79). Specifically, however, it means different things between Maintenance and Supply.

For maintenance, it is the time to reliably repair a part that it receives. For supply, it is the time to replenish a part in inventory once it has been issued to a flight line squadron. Broadly speaking, TRR is the time it takes to order a part, receive it, and place it on the shelf as ready for issue. To compute the TRR, the times to fill historical requisitions of a particular item are measured. The 90th percentile of those times is then applied as the TRR for that part (Seagren, 2013).

TRR is an important measurement in Marine Corps Aviation. MALSP MOD is structured around the ability to maintain consistent TRR measurements between various nodes within the logistic support framework. MALSP MOD is designed to reduce the supply footprint in forward deployed locations. According to MARADMIN 175/16,

> MALSP MOD is an improved expeditionary AVLOG concept that will provide more responsive, scalable, and flexible solutions through properly-sized spares packages while achieving near real time global visibility through an enhanced information technology (IT) and nodal logistics laydown (NLL) supply chain concept. (Headquarters Marine Corps, 2016, p.1)

In order to ensure a certain service level for flight line squadrons with a nodal, demand-pull logistics network, the TRR between nodes in the supply chain need to be relatively reliable and consistent. If the TRR between nodes contains great variance, inventory buffer levels have to be increased. Maintaining a large inventory at the different nodes is one of the very situations that a nodal logistics network is meant to avoid.

Optimizing TRR in this context can refer to either reducing the time it takes for maintenance to replenish the supply shelf or the time it takes for the supply chain (often the Defense Logistics Agency) to replenish the supply shelf. This metric does not measure the time to fill squadron requisitions. Optimizing this metric can be approached

in two different ways. First, it can mean reducing the TRR to as low of a number as possible. Second, it can mean making TRR as stable as possible.

The first is only helpful as long as variation is minimal. The second approach is more helpful, even if the TRR is larger. This is because the supply officer can maintain higher service levels with a reliable TRR through buffer size management than if the TRR is unreliable and widely varying. High variance in TRR requires larger inventory buffers to maintain satisfactory service levels during replenishment times, which is not always possible due to parts availability and budgetary constraints.

To demonstrate this, suppose the ASO desires a service level of 90%, demand for part X is constant with one per day, and lead time for part X (i.e., TRR) is not constant. A service level of 90% has a z value of 1.28. To determine the proper amount of safety stock (*SS*), the z value of the service level (z) is multiplied by the standard deviation of demand during lead time (σ_L) (Chase, Jacobs, & Aquilano, 2004, p. 557). Because demand is constant in this example, the standard deviation of demand during lead time (DDLT) will only increase as the standard deviation of lead time (i.e., variation) increases.

Table 6 summarily presents two scenarios that portray the two ways in which TRR can be optimized, reducing lead time and reducing variation in lead time. In Scenario A, AVLOG reduces mean TRR without also reducing the variability of TRR. In this example, TRR might be reduced to four days and the standard deviation of that replenishment time may also be four days. To maintain a service level of 90%, a safety stock of approximately five items needs to be held on the supply shelf.

Suppose in Scenario B, AVLOG chooses to reduce variability of TRR, rather than the mean TRR. In doing so, the resulting safety stock requirement is quite different. If TRR is eight days but variability of the replenishment time is two days, approximately two and a half items are needed as safety stock on the supply shelf to maintain a 90% service level. The TRR might be twice as much in this scenario but variability of that lead time is half, resulting in half the safety stock required.

Table 6. Safety Stock Requirements with Different TRR Variability

	Scenario A	Scenario B
Demand During Lead Time (1/day)	4	8
Standard Deviation of Lead Time (σL)	4	2
Service level desired (z)	90.00%	90.00%
Safety Stock *(SS = z * σL)*	5.13	2.56

Optimizing TRR through reduced variation can therefore be more beneficial than reducing mean TRR but allowing increased variation in replenishment times. Understanding the implications of variance in TRR is therefore essential for proper buffer size management. If buffer sizes are managed appropriately, TRR itself does not necessarily have any positive or negative impact on squadrons. The squadron is only negatively affected if they order a part that is not in stock. Whether a part's TRR is 60 days or 10 days, the squadron is only affected if the ASO's buffer is not sufficient to cover that transportation time.

3. Beyond Capability of Maintenance

The maintenance department occasionally encounters situations where they have a part that they are unable to repair. When this situation arises, the MAF receives an action code of Beyond Capability of Maintenance (BCM). There are various reasons a MALS may not be able to perform maintenance on a part. Examples include lack of parts, lack of repair equipment, or beyond authorized repair depth. The BCM codes, therefore, have accompanying identifiers to describe why the MALS is unable to perform the repair. These codes are identified in Table 7.

Table 7. BCM Codes

BCM 1	Repair Not Authorized	**BCM 4**	Lack of Parts	**BCM 7**	Beyond Authorized Repair Depth
BCM 2	Lack of Equipment, Tools, or Facilities	**BCM 5**	Fails Check and Test	**BCM 8**	Administrative
BCM 3	Lack of Technical Skills	**BCM 6**	Lack of Technical Data	**BCM 9**	Condemned

Parts being coded BCM are of concern due to the general higher cost of conducting repair at a higher level of repair, including the Depot level or manufacturer. It is generally cheaper to repair a part at the lowest level possible, with the flight line squadron being the lowest, followed by the intermediate level MALS. The maintenance department and supply department are both interested in BCM rates, albeit for different reasons. The supply department is primarily interested in BCM 4 codes because that is the code for which they have the most influence. The maintenance department, however, is concerned with all BCM codes.

High BCM rates may indicate that either the maintenance or supply department is unable to perform its job adequately. A maintenance department reporting a BCM 3 does not reflect positively on the maintainers within that MALS. If a MALS must BCM a repairable, the BCM 7 code is the one preferred. This is because it indicates that they have sufficiently done all they are authorized to do and are required to submit the part for a higher level of repair.

The BCM metric incentivizes cost-reduction through in-house repair of parts. Focusing on keeping low BCM rates, however, may diminish MALS support to flight line squadrons. There are often long periods of troubleshooting and repair before an item receives a BCM code (with the exception of BCM 1 and most BCM 7 codes). If the goal is to minimize BCM codes, then those periods of troubleshooting and repair will be further extended as maintainers continue to attempt successful repair. These longer repair times could potentially result in longer wait times for the flight line squadron who requires the part.

Optimizing BCM rates means to reduce the number of BCMs that occur, primarily BCM 4 and BCM 7. BCM 7 rates can be reduced through BCM interdiction, when a MALS receives authorization to conduct maintenance themselves or a local artisan that is not typical of the I-Level. BCM 4 rates can be reduced through parts acquisition and inventory management.

BCM rates only positively affect the flight line squadron if it results in a ready-for-issue part being issued to the flight line squadron more quickly than had the

part been sent off for repair and a ready-for-issue part been requisitioned. Low or high BCM rates themselves do not necessarily affect fill rates for flight line squadrons. As long as a MALS has spare parts on the supply shelf for the squadron, BCM rates are irrelevant (in terms of flight line squadron support).

4. Supply Effectiveness or Perfect Order Fulfillment

Supply effectiveness, or fill rate, is primarily a supply metric, measuring what percentage of demands are filled immediately upon requisition. Items that are not in stock or not carried in the supply system detract from the total percentage. If a requisitioned item is in stock, then that completed requisition will contribute to the total percentage. This metric is typically described as net supply effectiveness and gross supply effectiveness. Net supply effectiveness considers only items that are carried while gross supply effectiveness considers all requisitions. Balestreri and McDoniel (2002) define perfect order fulfillment in much the same way as supply effectiveness, though without net and gross distinctions.

This metric is beneficial for several reasons. First, it is easily calculated. Second, high fill rates have corresponding tangible effects. Third, it most easily discussed and communicated. There can be, however, negative aspects of this metric. Primarily, this metric can treat all requisitions as equal, requisitions that render an aircraft non-mission capable (coded AK0) or partial-mission capable (coded AK7). In order to capture this disparity, the ASO must filter for requisitions that are coded AK0 and AK7. Further filtering between consumables and repairables also improves the helpfulness of this metric, as this delineates between who may be responsible for filling a hole on a shelf (i.e., maintenance or supply).

Another negative aspect of this metric is the absence of any time dimension consideration. An AK0 requisition that is not immediately filled will degrade the supply effectiveness measure. If that requisition takes 10 or 40 days to fill, however, is not taken into account. These two scenarios have very different second order effects on a squadron. Dispatch rules that properly prioritize these outstanding requisitions by examining the time dimension of these requisitions will best impact the squadron.

Optimizing the supply effectiveness measure means ensuring that when a part is ordered, it is in stock. This often equates to minimizing holes on the supply shelf. Priority should be given to holes on the shelf whose respective parts are ordered the most frequently, however. The original MALSP model focused on optimizing fill rate, which resulted in greater range and depth on the supply shelf. The end result of such focus resulted in large inventories forward deployed.

Supply effectiveness connects the MALS very directly to the squadron and high supply effectiveness rates enable the squadron to best work towards improving flight line readiness. The effects of improved supply effectiveness are easily seen. It results in flight line squadrons receiving parts more often, that is, having less not-in-stock coded requisitions.

Focusing on supply effectiveness as a single metric, however, places the burden primarily on supply. Maintenance is not able to directly influence this fill rate without receiving direction from Supply. While maintenance does replenish the supply shelf, supply is still the first point of contact in answering for low supply effectiveness performance. Supply effectiveness is therefore a reasonable measure for the ASO to examine but less useful for the MALS as an entity.

5. IMA Effectiveness

An Expeditious Repair (EXREP) is when an intermediate maintenance activity (IMA) receives a non-RFI repairable part from a squadron and, because that part is rendering an aircraft NMCS or PMCS, needs to be repaired expeditiously. An EXREP is defined by the NAMP in this way:

> The processing for repair of NIS or NC components (repairable or consumable). These components must be in support of, or related to, an NMCS or PMCS, situation. This processing is accomplished by the immediate removal of the component from the aircraft, expedited delivery and induction for repair, and the earliest return to RFI status for supply issue under the standard material issue priority system. (Department of the Navy, 2012, p. A-25)

In a similar way that net or gross supply effectiveness is used as a performance metric for the supply department, the maintenance department may use EXREPs as a

basis for measuring performance. This metric is called “IMA Effectiveness” and is computed by dividing the number of EXREPs the IMA receives and how many of those are repaired and reissued as RFI. An EXREP occurs because there is not an asset on the Supply Officer’s shelf that can be immediately issued as RFI or the asset is not carried.

Optimizing this metric in the maintenance department will lead to the immediate needs of the squadron being met as long as the parts are repairable at the IMA level. Because the parts are immediately necessary to help resolve and NMCS or PMCS discrepancy, quick turnaround on EXREPs can more directly be linked to improved aircraft readiness than working on MAFs that fill yellow physical buffer status items on the supply shelf.

EXREPs, however, are indicative of holes on the supply shelf. A perfectly optimized supply chain may render EXREPs nonexistent. While maintenance will do well to ensure EXREPs are repaired and reissued quickly, the MALS could potentially avoid EXREPs if resources were effectively allocated towards physical buffer status red reductions, forecasting, and inventory management.

To achieve a high IMA Effectiveness ratio, a MALS must repair and reissue EXREPs within the same month they are issued, or reduce the number of EXREP occurrences. The former is accomplished through expedited repair processes by maintenance, the latter through physical buffer status red reduction by maintenance and supply jointly. Reducing EXREP occurrences more positively affects the squadron than expedited repairs because this metric is measured in terms of EXREPs per month, not time to complete an EXREP. If an IMA receives an EXREP on the first day of the month, the MALS will receive the same measure for IMA effectiveness whether they take 28 days or two days to reissue that item.

6. Supply Response Time

Supply Response Time (SRT) is a fairly direct metric and focuses specifically on the time between when a part that is on-station is requisitioned and when the squadron receives the part. High priority items, for example, have a target supply response time for

part delivery of one hour. This measurement is generally provided as an average of all delivery times or as a percentile.

Supply, however, does not have total control of the factors that affect SRT. Misaligned schedules of the MALS and the flight line squadron can render it impossible to deliver parts at certain times. A flight line squadron's operating schedule is more dynamic than a MALS operating schedule. For example, if a flight line squadron is operating on a limited schedule due to some personnel being gone for training detachments, there may not be personnel at the squadron to accept any delivered parts. This negatively impacts supply's SRT.

Optimizing SRT in its current construct (the positive measure of how many requisitions are delivered in the target time) may not have any remarkable effects on flight line squadrons. SRT is a positive measurement and thus is indicative only of deliveries made successfully within the target time. In this manner, it is a function of parts already on the supply shelf.

An SRT of 90% parts delivered within the target time is misleading regarding the level of service provided to the squadron. This is because the 10% of parts that were not delivered within the target time are unaccounted for in this metric. Furthermore, a portion of that 10% may be just outside of the target SRT. Delivering a part in four hours, when its target time was one hour, will not have any significant effect on aircraft readiness. Measuring only the on-station time of a requisition is therefore only marginally beneficial.

7. Supply Chain Response Time

The Supply Chain Response Time (SCRT) metric, as suggested by Balestreri and McDoniel (2002), seeks to resolve SRT's shortcomings in regard to accounting only for on-station time of a requisition. They define on-station supply response time as logistics response time and and the off-station time of a requisition as customer wait time. These two measurements are combined in the SCRT. This is helpful because supply response time examines only a portion of the logistics system's activity.

If SCRT is made a function of parts that were not delivered in their target delivery time frame, then the metric becomes much more useful and beneficial for both the MALS and the flight line squadron. By capturing this time as a negative measurement (rather than the positive measurement of how many items were delivered in the target time frame), the potential impact of delayed delivery can be better quantified and communicated. To do so, the MALS would measure only the parts that missed their target delivery time.

Categorizing those off-station requisitions according to their physical buffer status would further improve this metric. SRT construed in this way would be a negative measurement. As a negative measurement, it is much more indicative of the quality of support a MALS provides the squadron.

SCRT better affects flight line squadrons if taken as a negative measurement rather than a positive measurement. Focusing improvement efforts on reducing excessive delivery time results in the flight line receiving critical parts more quickly. Information of this sort will help the ASO allocate his resources more effectively to improve support to the flight line.

8. MALS Effectiveness

MALS Effectiveness is a type of performance measurement system used by several MALS seeking to provide a holistic view of maintenance and supply functions in one metric. The MALS Effectiveness metric is calculated by averaging the supply effectiveness metric (i.e., filled requisitions) and the IMA effectiveness metric (i.e., repaired EXREPs). If a MALS supply effectiveness metric is 80% and the IMA effectiveness metric is 60%, then MALS effectiveness is 70%. While supply effectiveness captures a large amount of the output from supply, EXREPs are only a small part of the output from maintenance.

For example, if a MALS has 800 requisitions and supply fills 700 of them, its supply effectiveness is 87.5%. If it has 30 EXREPs and reissues 15 and BCM codes the other 15, its IMA effectiveness is 50%. The MALS effectiveness of this MALS is therefore 68.75%. If supply achieved a measurement of 100% (i.e., filling the remaining

100 requisitions), MALS effectiveness would only increase to 75%. If supply's performance remained the same, maintenance would have to achieve a measurement of 62.5% (i.e., repairing only four more EXREPs) to achieve 75%.

Because of its disproportionate nature, focus on improvement to this metric may not greatly increase support to the squadron. To increase MALS Effectiveness in the previous example, maintenance may only need to RFI between five and ten EXREPs. Five to 10 parts out of 830 requisitions and EXREPs will benefit the squadron but not greatly.

E. MEASUREMENTS AND BEHAVIOR

Measurement systems will affect the behavior of those being measured. It has been discovered, however, that some measurement systems will have unintended consequences for overall performance. A result may be "that the types of behavior rewarded are those which the rewarder is trying to discourage, while the behavior is not being rewarded at all" (Kerr, 1995, p. 7). Another disparity between measurements and behavior can occur when a positive behavior is rewarded but "provides no actual benefit for the system" (Doerr & Gue, 2012, p. 726). This can occur when a dispatch rule or policy is internally focused and does not directly contribute to system output.

This section focuses primarily on examining current primary metrics used by the MALS and how they can influence the behavior of Marines in a MALS. Each metric has examined in detail in this section also in order to fully understand the metrics and how they are calculated. Further emphasis is placed on the behavior that each metric encourages within the MALS.

1. Buffer Management Tool—Buffer Status

The focus of the BMT system is to rightly prioritize maintenance in order to ensure the supply shelf is adequately stocked. By establishing a reliable benchmark for repair time of part, more reliable predictions can be made regarding repair completion. This is helpful for both the ASO and the squadron that requires that part. The ASO is better able to manage his inventory and buffer size for that part in order to ensure

continued availability of that part for the squadron. If parts take longer to repair than the benchmark then the ASO may not have the part when the squadron needs it. If the repair is repeatedly faster than the benchmark, then the ASO may have unnecessary extra parts on the shelf.

Proper use of the BMT will incentivize Marines to prioritize MAFs that, once completed, will fill empty spots on the ASO's supply shelf. The supply shelf becomes the customer that the maintenance department serves. This does not always directly correlate to the greatest needs of flight line squadrons, however.

Not all empty shelf spots have equal importance. The frequency and quantity at which an item is ordered dictates the level of importance it demands. An item historically requisitioned once a year will have a supply buffer status of red until it is replenished. An item requisitioned once a day will have the same buffer status. The buffer status color code itself does not indicate which item ought to take priority.

Optimizing BMT can have positive and negative effects on Marines' behavior. Positively, it theoretically encourages Marines to expedite repair or processing of the most needed parts—those that are buffer status red. Negatively, increasing the range of the supply shelf (i.e., adding parts to carry in inventory) may be discouraged. By increasing the number of parts that carried, there are more opportunities to have occurrences of buffer status red.

Design TRR numbers are easily manipulated and if a part repeatedly exceeds its Design TRR, the TRR can simply be increased with much less effort than attempting to improve the repair process. If BMT is optimized, Design TRR will have to be accurate. Ensuring these numbers are accurate is manpower intensive (under the current construct). Allocating resources to ensure Design TRR numbers are current and accurate incurs great opportunity cost, as every man-hour spent on such a task is one less man-hour spent on repairing parts.

2. Time to Reliably Replenish—TRR

Focusing on TRR as a primary metric for a MALS may result in increased inventory levels because to account for the variation of supplier or maintainer times (direct factors of supply's TRR), a larger buffer of spares is required. With increased inventory levels come increased costs. This was the model of MALSP I but is contra to the underlying principle of MALSP MOD.

However, it does increase the level of support provided to supported squadrons. Reduced TRR and increased inventory results in squadrons having what they need more quickly. In a fleet of aging aircraft, however, increasing inventory of certain dynamic components can be expensive at best and infeasible at worst.

In order to optimize TRR, the processes for forecasting shortages must be improved. Currently, there is no framework for forecasting what may reach buffer status red without timely replenishment. An algorithm that factors historical demand, current buffer status, and estimated time to delivery can provide a rough indication of whether a part will arrive before it is requisitioned by a squadron. Any parts indicated by such a calculation could then be opportunities for the ASO to begin expediting before they become needed for down aircraft.

3. Beyond Capability of Maintenance

Optimizing BCM generally means making every effort to repair parts in-house, also called BCM interdiction. A likely result of this is elongated repair times, as a MALS spends more time troubleshooting a problem or seeking authorization to conduct certain repair procedures normally reserved for higher levels of maintenance. If these parts are needed by the squadron, then delivery may be delayed.

A reasonable MALS will not conduct BCM interdiction on a part that is needed immediately. However, if BCM interdiction begins first on a low priority part and then the part becomes high priority, delivery of an RFI part may be delayed due to previously started BCM interdiction. In this scenario, BCM interdiction can have negative consequences.

BCM interdiction can also be problematic when it requires resources that may otherwise be better spent on other maintenance. Determined Marines may spend an inordinate amount of time trying to repair a part when it could be more efficiently repaired elsewhere. While BCM-ing a part may be more expensive, reduced aircraft readiness may arguably be more expensive in terms of opportunity cost.

4. Supply Effectiveness or Perfect Order Fulfillment

Optimizing supply effectiveness encourages Marines to increase inventory buffers in order to ensure parts are available when requisitioned. This leads to increased inventory and holding costs. However, because supply effectiveness is generally reported in terms of Net or Gross terms, increasing the range of the supply shelf may be discouraged.

Supply effectiveness is a measurement that attempts to capture the output of a MALS to its customer. However, similar to SRT, it does not adequately capture the negative impact of the requisitions that go off-station due to being not-in-stock or not carried. The vast majority of conversations between the Maintenance Officer, Supply Officer, and squadron Maintenance/Material Control Officers revolve around those off-station parts.

5. IMA Effectiveness

The IMA Effectiveness metric positively increases by repairing and reissuing EXREP parts to the squadron in the same month that they are received. A MALS will receive a 100% IMA Effectiveness if they receive and reissue one-of-one EXREPs or 30-of-30. Reducing EXREPs, therefore, does not decrease IMA Effectiveness.

If this metric is used as a focal point for performance measurement then all of a work center’s resources will be dedicated to that EXREP when it is received. If the EXREP cannot be repaired by the work center, then that part receives a BCM code and is sent to a higher level of maintenance. A MALS generally makes every effort to quickly return EXREPs to the squadron or quickly BCM the item in order to requisition an RFI asset.

When an EXREP is received, a work center's attention is turned away from its current task to repair the inducted EXREP item. This pulls manpower away from maintenance on other items, potentially critical buffer status red items. This is the only case when allocated resources to an EXREP item may prove problematic. Even so, EXREPs are generally a very small portion of an IMA's total MAF count and therefore do not drastically impair progress on current maintenance being conducted. Because EXREPs are such a small portion of an IMA's workload, using them as a metric for effectiveness falls short of capturing the IMA's activity as a whole. Supply effectiveness is a much more holistic measure of the supply department than IMA Effectiveness is of the maintenance department.

6. Supply Response Time

Focusing on SRT may lead to expeditious delivery of priority parts that are in stock. As requisitions are placed, high priority parts (determined by their priority code) will be delivered first because they have the shortest time requirement. Lower priority parts have longer target times to be delivered.

SRT is normally calculated as a percentage of requisitions that were filled within the target timeframe. In this regard, it is a positive measure communicating the successes of the supply department. SRT construed in this manner can negatively affect supply personnel behavior, however.

A MALS supply department may generally have an SRT success rate of 90%. This means that 90% of all requisitions were delivered within the target timeframe. Framing the metric in this positive manner does not communicate the negative affect the remaining 10% may have on the flight line squadrons. A positive metric of 90% may create a culture of complacency within Marines as it diverts the focus from improvement opportunities.

If the metric is communicated in a negative sense, it will focus on the remaining 10% that did not meet the target time frame. Furthermore, if the metric is communicated not as a ratio but as a time, then the information is much more meaningful. Examining a certain percentile of delivery times of the 10% that did not meet the target time frame not

only highlights improvement opportunities but better communicates how the flight line squadrons are being affected.

7. Supply Chain Response Time

SCRT measures the total time on- and off-station of a requisition. If the measurement is reported negatively (i.e., only measuring those requisitions that missed their target delivery time), then the MALS can gain a better understanding of how the logistics network is impacting the flight line squadron. A negative measurement better communicates to the logistics system how it may be hindering aircraft readiness. It also more clearly identifies where process improvements can be made.

In the same way that SRT reported positively may create a sense of complacency among Marines, SCRT may do the same. If a SCRT success rate of 90% is reported, then the MALS is delivering 90% of requisitions in the target time. However, the remaining 10% are the requisitions that are immediately affecting the flight line. Separating the remaining 10% into high and low priority documents can better focus MALS' efforts on the critical few parts that are negatively affecting the flight line.

Because SRT only measures on-station time, and SCRT combines both on-station and off-station time, SCRT is much more helpful as a measurement. While it is true that a MALS does not fully own any of the off-station supply chain processes, it does have a great deal of influence on them. Expediting requisitions, negotiations with item managers, and trade-offs with other MALS are all ways that a MALS can reduce off-station time of a requisition.

8. MALS Effectiveness

Giving equal weights to supply effectiveness and IMA effectiveness, the two metrics that are averaged to determine MALS effectiveness, is disproportionate. A much greater amount of work must be done by the supply department than the maintenance department to increase the metric. Only a small portion of the IMA's workload is captured by this metric. Because of the disproportionate nature of this metric, optimizing this metric may result in demoralizing supply department Marines due to the

disproportionate amount of work they must exert to increase their effectiveness in comparison with the maintenance department.

In the maintenance department, Marines' behavior may not change very drastically. EXREPs are a small portion of their regular workload and only receive attention when they are received. Once received, they are prioritized above the regular workload and every effort is made to repair the item as quickly as possible. If it cannot be repaired in-house, it is BCMed and is sent to a higher level. Once either of these events takes place, the Marines return to their regular workload. Because EXREPs are not part of their regularly managed workload, focusing on MALS Effectiveness will not incentivize greater production on a day-to-day basis for work centers.

F. CRITERIA APPLIED

To evaluate and compare the discussed metrics, Caplice and Sheffi's (1994) evaluation criteria are used and adapted for relevancy to the MALS. Table 8 summarizes the criteria and provides examples of the types of questions asked regarding each metric. Each metric is then scored according to these criteria. A score of "5" indicates that the criterion describes that metric very well. A score of "1" indicates that the criterion poorly describes that metric. The scores are then averaged for a total score of that metric.

Table 8. Evaluation Criteria. Adapted from Caplice and Sheffi (1994).

Validity	Does it capture the events and activities being measured and controls for external factors?
Robustness	Is it interpreted similarly by users? It is comparable between MALS? Is it repeatable?
Usefulness	It is readily understandable by decision maker? Does it provide a guide for action to be taken?
Integration	Does it include all relevant aspects of the process? Does it promote coordination across functions?
Economy	Does the benefit of using the metric outweigh the costs of data collection, analysis, reporting?
Compatibility	It is compatible with existing information, material, and systems in the organization?
Level of Detail	Does it provide a sufficient degree of granularity or aggregation for the user?
Behavioral Soundness	Does it minimize incentives for counter-productive acts or game-playing? Is it presented in useful form?

1. Buffer Management Tool

The BMT captures a great deal of data regarding maintenance and supply functions. The Physical Buffer Status Red metric is one of the most often used metrics produced by this system. The data is easily collected and the metric is easily communicated. It quickly focuses maintenance and supply leaders on critical needs on the supply shelf.

However, due to the variety of squadrons supported by different MALS, the number of physical buffer status red items does not communicate what level of support is provided to squadrons in comparable terms. Physical buffer status red also does not communicate information regarding what parts are currently needed on the flight line. An item does not have to be requisitioned in order to have a red physical buffer status. Table 9 summarizes the evaluation of this metric according to the proposed metric criteria.

Table 9. Metric Criteria and BMT

Metric Criteria	Buffer Status Red (BMT)
Validity	5
Robustness	3
Usefulness	4
Integration	4
Economy	4
Compatibility	5
Level of Detail	5
Behavioral Soundness	4
Sum	34

2. Time to Reliably Replenish

The MALSP MOD nodal logistics laydown framework is largely built upon the TRR concept and thus this metric is a commonly understood idea across AVLOG organizations. TRR can be defined in both maintenance and supply terms. As a maintenance concept, it is founded on the Design TRR of parts. The Design TRR is easy to manipulate, difficult to maintain accuracy, and arbitrary if applied to multiple parts

based on a single part's analyzed TRR. As a supply measurement, it is founded on the historical replenishment times of parts through the supply chain, and is therefore more reliable and useful.

TRR does not measure the output of a MALS and does not reflect the quality of support a MALS provides to squadrons. While it is a helpful metric for a sub-function in AVLOG, it is less helpful when measuring MALS performance. Table 10 summarizes the evaluation of this metric according to the proposed metric criteria.

Table 10. Metric Criteria and TRR

Metric Criteria	TRR
Validity	3
Robustness	3
Usefulness	3
Integration	3
Economy	2
Compatibility	5
Level of Detail	3
Behavioral Soundness	2
Sum	24

3. Beyond Capability of Maintenance

BCM is a metric that is used in every MALS but is not directly comparable between different MALS. This is due to the different repair capabilities and support requirements at each MALS. For example, new aircraft may have more parts that have to be automatically BCM coded than legacy aircraft parts due to proprietary information of manufacturers. It is easily calculated and communicated, however.

BCM accurately captures a portion of MALS activity but it does not capture MALS output. Rather, it measures when maintenance is not able to repair a part in-house. Because a BCM part does not directly affect flight line squadron support, it is less helpful in measuring MALS performance. Table 11 summarizes the evaluation of this metric according to the proposed metric criteria.

Table 11. Metric Criteria and BCM

Metric Criteria	BCM
Validity	4
Robustness	3
Usefulness	4
Integration	2
Economy	3
Compatibility	5
Level of Detail	4
Behavioral Soundness	3
Sum	28

4. Supply Effectiveness or Fill Rate

Supply Effectiveness is a commonly used and well understood metric. It is computed easily and directly measures the output of a MALS. It is comparable between MALS but is most helpful if it is compared between T/M/S at each MALS. This will identify any potential systematic support issues in a T/M/S that are AVLOG wide issues.

Presenting this as a positive metric (i.e., successes rather than failures) may discourage process improvement as this metric is generally quite high. Presented negatively with emphasis on NMCS and PMCS parts, however, focuses leaders' attention on the critical few items that are negatively affecting the flight line. The evaluation of this metric according to the proposed metric criteria is summarized in Table 12.

Table 12. Metric Criteria and Supply Effectiveness

Metric Criteria	Supply Effectiveness
Validity	4
Robustness	4
Usefulness	4
Integration	4
Economy	4
Compatibility	5
Level of Detail	4
Behavioral Soundness	3
Sum	32

5. IMA Effectiveness

IMA Effectiveness only captures a very small portion of IMA activity. This metric is not used by all MALS and is therefore not currently comparable between MALS. This metric is a factor of repair capabilities and support requirements and therefore is further limited in comparability between MALS.

It is an easily calculated and understood metric, however, and may help the AMO and ASO identify process improvement areas. Because delivering an RFI part to the squadron is the goal, it must be the focus of this metric. Therefore, the quickest route (i.e., BCM or repair) to delivery that RFI part should be pursued. If this metric is optimized, it may encourage Marines to troubleshoot parts longer than it would take to order and receive a part once BCM coded. The evaluation of this metric according to the proposed metric criteria is shown in Table 13.

Table 13. Metric Criteria and IMA Effectiveness

Metric Criteria	IMA Effectiveness
Validity	2
Robustness	3
Usefulness	3
Integration	2
Economy	3
Compatibility	4
Level of Detail	2
Behavioral Soundness	3
Sum	22

6. Supply Response Time

Supply Response Time measures delivery times against target times that are standardized for all MALS. These target times are only applicable to requisitions once they are on station. This limits the scope of this metric as it only captures a small portion

of the supply chain. It does not focus leaders' attention on areas that can have significant impact on the quality of flight line support.

Using this metric does not contribute greatly to improving flight line support if optimized. While this is the only portion of the chain that MALS completely owns, it is not the only portion with which they have influence, and thus this metric is too narrowly focused. The evaluation of this metric according to the proposed metric criteria is given in Table 14.

Table 14. Metric Criteria and SRT

Metric Criteria	SRT
Validity	3
Robustness	3
Usefulness	3
Integration	2
Economy	2
Compatibility	5
Level of Detail	3
Behavioral Soundness	3
Sum	24

7. Supply Chain Response Time

Supply Chain Response Time is a more holistic measurement of the wait time a squadron faces from requisition to delivery. Focusing on NMCS and PMCS requisitions improves the usability and applicability of this metric. It can be easily compared between MALS though it should be subdivided for each T/M/S that the MALS supports.

This metric is not currently used among the MALS, however. Also, it accounts for a great deal of time that is not controlled by the MALS. Using this metric may enable AVLOG leadership to better focus process improvement efforts on systematic issues. The evaluation of this metric according to the proposed metric criteria is shown in Table 15.

Table 15. Metric Criteria and SCRT

Metric Criteria	SCRT
Validity	4
Robustness	3
Usefulness	5
Integration	4
Economy	4
Compatibility	5
Level of Detail	4
Behavioral Soundness	4
Sum	33

8. MALS Effectiveness

MALS Effectiveness is not a standard metric used by all MALS. While it captures the majority of output from the supply department, it only narrowly captures the output from the maintenance department that it captures. A high priority on EXREPs is standard among MALS and thus this metric can be easily communicated and understood.

Because this metric is an average of two other metrics (supply effectiveness and IMA effectiveness), the result is equal emphasis on each metric. This is misleading however and using this as a performance measurement may encourage counter-productive behavior among Marines. The evaluation of this metric according to the proposed metric criteria is shown in Table 15.

Table 16. Metric Criteria and MALS Effectiveness

Metric Criteria	MALS Effectiveness
Validity	3
Robustness	2
Usefulness	2
Integration	2
Economy	2
Compatibility	4
Level of Detail	2
Behavioral Soundness	2
Sum	19

G. SINGLE, MULTIPLE, AND WEIGHTED METRICS

A single logistic metric is limited in the information it can provide about an organization's overall performance and is thus insufficient as a holistic performance measurement system. A MALS has many individual metrics available to measure its plethora of sub-functions. These combined sub-functions produce a corporate output. If a single metric must be used to measure the performance of the MALS, it should be the metric that captures this output most thoroughly and in terms that are indicative of the impact a MALS has on the flight line.

No single metric currently used, however, perfectly captures the output of a MALS. Deliveries are the primary and majority output of a MALS but other smaller outputs exist. To capture all the outputs of a MALS, a performance measurement system consisting of multiple metrics must be used. Metrics that capture these outputs would be reported together as indicative of performance. A group of multiple metrics may be used, therefore, as a performance measurement system. Groups of metrics, however, can become confusing when being communicated. Additionally, if every output of the MALS is captured, the number of metrics may become cumbersome.

Multiple metrics may then be combined into a single performance metric. This method has advantages and disadvantages. It captures multiple metrics into one and is therefore more easily communicated and briefed. However, if a simple average is taken, equal weight is being applied to all sub-metrics. This problem is seen in the MALS Effectiveness metric.

Applying appropriate weights to each of the sub-metrics that are reflective of the amount of output or importance of the sub-function that is measured is one way to avoid this flaw of averages. The Navy Submarine Fleet Maintenance program (Submarine Fleet Maintenance Metric Working Group, 2013) approaches their performance measurement in this fashion. This method scales each metric according to the proper amount of influence or importance it has in the overall system.

A system of appropriately weighed metrics is still not without problems, however. A high score on one metric may be negatively skewed by a very low score on another

metric. When this is the case, presenting only one combined metric will not present any indication of this problem. To control for this, each sub-metric may be assigned a goal and a lower control limit. If a sub-function is drastically underperforming (i.e., it is scoring below a sufficient level) then that can be identified through the use of a lower control limit. An overall combined performance measurement can still be presented and if there are any outliers that are underperforming, more detail may be provided.

H. PERFORMANCE MEASUREMENT SYSTEMS

The creation of a performance measurement system for a MALS ought to abide by the six criteria proposed by Caplice and Sheffi (1995), summarized in Table 17. Doing so will ensure the organization is able to make proper decisions to provide the best support to the customer. A performance measurement system views the organization in a holistic manner; a sum of parts rather than many separated processes.

Table 17. Measurement System Criteria. Adapted from Caplice and Sheffi (1995)

Measurement System Criteria
Comprehensive
Causally Oriented
Vertically Integrated
Horizontally Integrated
Internally Comparable
Useful

A comprehensive performance measurement system for the MALS will include metrics that capture maintenance and supply department outputs as well as customer service. These are the primary stakeholders in a MALS and thus should be a focus of a performance measurement system. Not including stakeholder perspective in a measurement system will lead to actions taken that may negatively affect one of them.

A causally oriented performance measurement system will measure activities that directly influence MALS performance. Performance, in this sense, is understood as

current and future performance (Caplice & Sheffi, 1995). Performance for a MALS is primarily a factor of RFI parts delivered to squadrons.

A performance measurement system that is vertically integrated in a MALS will clearly communicate the goal and strategy of the MALS to department, division, and work center leaders. It will be reflective of the overall goal of the MALS. Marines will understand how their role contributes to improving performance because performance is clearly defined.

A horizontally integrated performance measurement system in the MALS will include “pertinent activies, functions, and departments along the process” (p. 63). To do so, meaningful and causally oriented metrics from MALS’ major sub-functions need to be included. This results in greater integration and cooperation in a MALS.

An internally comparable performance measurement system is one that can demonstrate how trade-offs can be made among processes in the MALS to increase performance. An example of these trade-offs may be how repairing physical buffer status red items and deliving parts may affect one another. If the measurement system is internally comparable, then the metrics affect and are affected by one another.

Lastly, a performance measurement system ought to be useful to MALS leadership. It should be “readily understandable by the decision maker and provide a a guide for action to be taken” (p. 65). If it is too complex, the meaning of the metrics will be ignored. If the metrics do not seem meaningful, they will not be perceived as beneficial and therefore will not be used.

I. MALS AND T/M/S

No MALS is alike in terms of the T/M/S aircraft it supports. Because of these differences, metrics are not directly comparable MALS-to-MALS. The performance of a MALS that supports multiple H-1 squadrons cannot be directly compared to a MALS that supports multiple F-18 squadrons. This is due to the systematic differences of supporting certain aircraft. Systematic supply issues for a specific T/M/S can skew metrics unfairly.

In order to compare different MALS, the metrics should be MALS and T/M/S specific. MALS-24 in Hawaii should have different metrics for H-1 squadrons and CH-53 squadrons, for example. If the CH-53 fleet is encountering systematic supply issues, the quality of support for the H-1 squadron will not be negatively impacted.

A MALS and T/M/S specific measurement system will result in a MALS reporting measurement for each T/M/S they support. As an example, MALS-24 will report a performance metric for their H-1 squadron, their CH-53 squadron, and their V-22 squadron. When this delineation is made in the performance metric, MALS support for H-1 aircraft can be compared across all MALS that support H-1 aircraft. From a systems perspective, this gives AVLOG leaders an opportunity to identify where resources should be allocated to ensure flight line squadrons have what they need to succeed.

J. CHAPTER SUMMARY

Currently, the MALS examines itself according to several logistics metrics. No performance measurement system is currently used to evaluate the MALS performance as a whole and current metrics are insufficient to appropriate capture the output of the MALS. A proper performance measurement system must be a product of both maintenance and supply metrics that measure functions in a MALS. Returning to Caplice and Sheffi's work (1995), deliveries to customers are the output of a logistics system and thus should be the focal point of a logistics performance measurement system.

The metrics a MALS uses now adequately convey the performance of sub-functions within the organization. Optimizing each metric has different implications for the performance of the organization as a whole (in terms of support for flight line squadrons) and for the behavior of Marines in the MALS. Choosing any one of these metrics individually to be used as the measurement system for the MALS can have negative second- and third-order effects on the support a MALS provides to flight line squadrons.

A MALS's extent of control ceases at the point of delivery to a squadron. The goal of the MALS, therefore, cannot extent beyond this point. Increased aircraft readiness, therefore, cannot be the goal of a MALS. The MALSP MOD nodal logistics

system is strongly indicative of Marine Aviation's intent to operate in a lean, efficient manner. Increasing inventory levels to support flight line squadrons is no longer part of the model and thus emphasizing metrics that encourage that type of behavior is to be discouraged.

V. CONCLUSION AND RECOMMENDATIONS

A. CONCLUSION

The MALS has many metrics available that measure its various sub-functions, though they vary in degrees of usefulness. For a metric to be a valuable logistic measurement, it needs to meet certain criteria. The predominant MALS metrics are evaluated against the criteria proposed by Caplice and Sheffi (1994) and summarized in Table 18.

Table 18. Summary Comparison of Metrics and Evaluation Criteria

Metric Criteria	Buffer Status Red (BMT)	TRR	BCM	Supply Effective-ness	IMA Effective-ness	SRT	SCRT	MALS Effective-ness
Validity	5	3	4	4	2	3	4	3
Robustness	3	3	3	4	3	3	3	2
Usefulness	4	3	4	4	3	3	5	2
Integration	4	3	2	4	2	2	4	2
Economy	4	2	3	4	3	2	4	2
Compatibility	5	5	5	5	4	5	5	4
Level of Detail	5	3	4	4	2	3	4	2
Behavioral Soundness	4	2	3	3	3	3	4	2
Sum	34	24	28	32	22	24	33	19

The most useful metrics (e.g., physical buffer status red, supply chain response time, supply effectiveness) sufficiently fulfill their purpose for measuring their respective function within the MALS. Even these metrics, however, largely fall short in measuring the overall output of the MALS and thus do not meet the standard for a performance measurement system. For a performance measurement system to be most beneficial to the organization, it needs to meet the criteria proposed by Caplice and Sheffi (1995) for a performance measurement system. Individual metrics are unable to be comprehensive or horizontally integrated (1995.).

1. Primary Questions

(1) Of the metrics that MALS currently employs, which measures (or combination thereof) most appropriately reflect the level of support the MALS provides the flight-line?

Of the metrics that MALS *currently* employs, Supply Effectiveness most appropriately reflects the level of support the MALS provides the flight-line. This metric most comprehensively measures the majority output of the MALS. Of the current metrics, it best captures the overall function of the MALS. Most sub-functions within the MALS contribute to this end metric in some manner.

This metric is not necessarily ideal, however. It is not very descriptive in terms of what drives high or low support. In order to know how to improve Supply Effectiveness, leaders must examine separate metrics individually to determine the errant process. This metric gives leaders no indication of where to find the underlying problem.

Furthermore, this metric is framed positively, is inclusive of high- and low-priority requisitions, and provides no time domain. By constructing the metric in this manner, no indication is provided about the true level of support a MALS is providing. If Supply Effectiveness is 90%, it may be understood that a high level of support is being provided. If that 90%, however, is primarily low priority consumable requisitions and the remaining 10% are primarily NMCS requisitions that have remained off-station for 30 days, then the true level of support may be actually quite low. This metric lacks sufficient detail to inform leaders about the true level of support provided to a flight-line squadron.

(2) Of the metrics that MALS currently employs, which measures most appropriately incentivizes the most appropriate behavior to support the flight-line?

Of the metrics that MALS *currently* employs, Repairable Physical Buffer Status Red and TRR-Supply incentivize the most appropriate behavior to support the flight-line. Physical buffer status red incentivizes maintenance and supply to both focus work efforts on those items which, if requisitioned by the flight-line, will not be able to be filled. Prioritizing these items contributes to filling these holes on the supply shelf so they are available when needed. TRR-Supply incentivizes proper forecasting, expediting, and

inventory management. A reliable TRR metric aids in proper inventory management and prioritization of expedited requisitions. By examining TRR more closely, supply is able to adjust inventory levels or expedite requisitions appropriately to increase supply effectiveness.

(3) Are there metrics that MALS does not employ that should be adopted?

Two metrics should be adopted by the MALS. First, the Supply Chain Response Time metric should be adopted as a logistic metric. Second, a weighted performance metric should be adopted as an overall performance system.

First, Supply Chain Response Time should be adopted by the MALS, specifically in regard to NMCS and PMCS requisitions by T/M/S aircraft. By measuring the squadron's total on-station and off-station wait time for NMCS and PMCS requisitions, a stronger signal is sent to the entire supply chain than by just measuring on-station wait time. While it is true that the MALS only controls the amount of time a part is on-station, it is also true that a MALS has influence on portions of the supply chain which it does not own.

Capturing this time domain of the supply chain from the customer's perspective is an excellent measure of customer satisfaction. Furthermore, by capturing this metric according to the various T/M/S a MALS supports, systematic issues are more easily identified. A MALS may have a low average for SCRT but, unless it is delineated by T/M/S, poor support for a particular T/M/S may be masked due to a misleading average.

Second, a weighted performance metric should be adopted as a performance measurement system for each T/M/S a MALS supports. This is helpful in unifying the MALS under one common goal that is specific and measureable. The primary components of this performance metric should be:

- Physical Buffer Status Red of Repairables: The percentage of repairable items carried that have a physical buffer status of red
- Supply Chain Response Time: The percentage of NMCS and PMCS requisitions that went off-station with an SCRT exceeding a certain threshold

- Supply Effectiveness: The percentage of NMCS and PMCS requisitions that went off-station

By presenting these metrics as percentages, they can more easily be compared to other MALS that support the same T/M/S. These metrics provide a holistic view of the output of a MALS and provide enough detail to MALS and AVLOG leadership to identify why support for a flight-line squadron may be poor. Condensing this performance metric to these three individual metrics enables easy communication of the metric.

While these metrics do not completely capture the output from a MALS and all the services they perform for squadrons, they do summarize the majority of the output from maintenance and supply departments. Though the Repairable Physical Buffer Status Red metric is a measure of the health of the supply shelf, maintenance is primarily responsible for replenishing those repairable items. The SCRT metric captures the impact off-station items have on the flight-line. The Supply Effectiveness metric captures both consumable and repairable requisitions that went off-station.

By combining these metrics into one measurement, there is a possibility that the end measurement may fail to identify problems at a MALS due to the flaw of averages. For example, a performance measurement goal of 85% can be reach if all three measurement score 85%. It can also be reached by averaging scores of 90%, 95%, and 70%. By reporting only the end average, the lower 70% metric remains unidentified. To counteract this, each measurement should have an appropriate goal to define what success is and lower control limit to define what failure is. If a measurement falls below the lower control limit, it ought to be reported separately in order to identify the area for potential troubleshooting.

To be meaningful, the SCRT metric needs to be measured in regard to a certain threshold. A threshold of three days, for example, measures the number of requisitions exceeding three days in customer wait time. Capturing this time domain is a strong indicator of responsiveness of the supply chain.

2. Secondary Question

(1) To what extent can standardized performance measurements be used to measure flight-line support performance between various MALS?

In order to measure and compare flight-line support performance between various MALS, the measurements need to first be T/M/S specific within each MALS. This accounts for the systematic differences between different fleets of aircraft. Legacy aircraft, upgraded aircraft, and new T/M/S all have different support systems. A MALS may have very limited repair capability on a new T/M/S due to manufacturer proprietary rights. Conversely, a MALS have a great deal of repair capability on decades-old legacy aircraft.

If a MALS does not measure its performance according to T/M/S, then that MALS cannot be compared with other MALS. A MALS that supports primarily H-1 aircraft cannot be directly compared with a MALS that supports primarily F-18 aircraft. The types of repairs required, availability of parts, and mission requirements for these different aircraft limit the ability to compare their supporting MALS on like terms.

By measuring performance according to T/M/S, AVLOG leadership is better able to identify where it should allocate resources for process improvements. Systematic difficulties in the CH-53 community, for example, will be difficult to identify if those maintenance or supply issues are not captured separately. Poor support performance for a particular T/M/S may be disregarded if it is averaged in a conglomerate metric with all T/M/S.

B. RECOMMENDATIONS

The first recommendation is to include a time domain when measuring the performance of a MALS. A time domain is generally absent among the majority of metrics used within the MALS. Unfilled requisitions do hinder flight-line squadrons from receiving the parts that they need, but the true impact of unfilled requisitions cannot be understood without measuring how long squadrons waiting to receive those parts. A requisition for an NMCS discrepancy has very different implications for a squadron if it is delivered 30 days rather than three days.

The second recommendation is to ensure metrics are T/M/S specific. Resources may be misallocated if MALS are compared to one another without this distinction. By measuring a fleet of aircraft more holistically, a stronger signal is sent when a systematic problem occurs.

The third recommendation is to not abandon logistic metrics of internal functions within a MALS when adopting a holistic performance metric for the MALS. The internal logistic metrics are the primary way in which leaders can identify why the MALS performance measurement may be low or what is causing it to succeed. Internally, departments and divisions should continue to measure their internal processes. These internal metrics, however, need to be understood in relation to the MALS performance metric and how they affect one another.

Lastly, further research is recommended in two areas. First, cross validation of the scores given to individual metrics in this study should be conducted. Subject matter experts from the AVLOG community ought to independently score the metrics and then the inter-rater reliability or correlation between the scores can be measured. Second, appropriate weights ought to be determined for each metric used in the final performance metric. AVLOG leaders may determine if these metrics should be assigned equal weight or if any of them should receive more or less weight for final computation. Weights could also be assigned by analyzing the level of influence each metric’s performance has on total MALS output. This will prevent any of the measurements from unnecessarily skewing the measurement due to disproportionate allocation of weight.

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